AFIT/GSM/LAR/93S-1

A STUDY OF USN AIRCREW ATTITUDES REGARDING TECHNOLOGY'S ABILITY TO REPLACE THE NAVAL FLIGHT OFFICER ON TYPICAL COMBAT MISSIONS CARRIER BASED AIRCRAFT ARE TASKED TO PERFORM

THESIS

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THESIS

Presented to the Faculty of the School of Logistics and Acquisition

Management of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degrees of

Master of Science in Systems Management

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September 1993

Preface

The purpose of this study is to examine USN pilot and Naval Flight Officer attitudes regarding technology and its impact on crew complement for a number of typical combat missions carrier based aircraft are tasked to perform. This study is a follow-on effort to a similar effort conducted in the USAF to determine the impact on mission effectiveness given new cockpit automation. The authors of the USAF study expressed concern that the USAF was leaning heavily on technology in an effort to reduce personnel costs. This USN study uncovered evidence to suggest that crew complement decisions may in fact be made with political and economic factors as the overriding concerns. Both the USN and USAF are in the process of designing their next generation combat aircraft. Additionally, changes in employment doctrine are evolving rapidly. It is imperative that decisions regarding crew complement include mission success and survivability.

The authors of this study come from diverse backgrounds within military aviation. Captain Britt is a USAF fighter pilot experienced in the F-16 and A-10 . Lieutenant Cain is a USN A-6E bombardier/navigator. This diversity in our experience has hopefully provided objectivity to the study. Our beliefs going into this study were that there in fact were missions that could effectively be executed by a single pilot. We also believed that current, and likely future, technology has not developed sufficiently to allow successful and survivable operations in all mission and threat scenarios. To validate our beliefs and to compare findings with the USAF study, we surveyed 290 USN pilots and

NFOs currently assigned to duty involving operational flying in six active airwings. These pilots and NFOs came from four different type aircraft, the F/A-18 Hornet, the A-6E Intruder, the F-14 Tomcat, and the EA-6B Prowler. The aircrew were asked to assess both survivability and mission success for one- and two-seat operations in six typical air-to-air and air-to-ground missions. These assessments were made both in the context of current aircraft capability and perceived future aircraft capability. The assessments were compiled, analyzed, and evaluated to answer our research question. The results of the study substantiated our beliefs in this issue.

We would like to thank the people who made this research effort possible. Without the support of our families, this research would have been difficult at best. The requirements of such an undertaking are considerable and as a result time is always a premium. Our families' understanding of these requirements made this effort a success. We would also like to thank our advisors, Dr. Kirk Vaughan and Dr. Guy Shane, for their expert guidance and ability to keep us focused.

Finally, we would like to thank the pilots and NFOs who took the time to participate in this survey. The comments received indicate this is an important issue to them, and many of them possess strong convictions regarding it. It is our hope that we were able to accurately represent their attitudes in this study. It is not our aim to provide a decision for crew requirements in any particular mission. It is our aim to provide operator input in representative numbers for use by Department of Defense decision-makers.

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Abstract

This study analyzed survey responses of 290 Navy pilots and Naval flight officers (NFOs) regarding their perceptions of technology's ability to replace the NFO in typical combat missions carrier-based aircraft are tasked to perform. The study is a follow-on to a similar USAF effort conducted with pilots. The objective of this study is to provide operator input to the critical crew complement issue. These missions vary significantly in complexity and in demands placed on the aircrew. The survey instrument and analysis methods were designed to detect and evaluate these differences. The USAF study concluded that the perception of a requirement for additional crewmember(s) varied with mission and type aircraft flown. The USN aircrew analysis indicates perceptions also vary in both of these categories. There is evidence to suggest that technology is making gains with regard to aircrew workload in certain mission areas. On the other hand, there are also areas where an additional crewmember is considered a requirement. This study will examine each of these mission areas in both a current and future technology context. From this examination a relative ranking of NFO contribution in all of the mission areas analyzed is provided. Aircrew perceptions of crew requirements across these missions clearly indicate caution in wholesale replacement of crewmembers by technology.

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I. INTRODUCTION

Chapter Overview

There is currently much debate regarding crew complement requirements for U.S. military combat aircraft. The central issue from a performance standpoint appears to concern technology and its ability to decrease cockpit workload. This thesis presents a look at the crew complement issue as it specifically pertains to U.S. Navy fighter and attack aircraft. Before the specific issue can be addressed, one must look at a broader set of issues which more thoroughly define the depth of the problem of crew complement. This chapter contains material supporting that broad look. Detailed background information supporting both the general and sub-issues is provided in Chapter 2.

Despite the significance of this issue, there are few studies that specifically address it. This research statistically evaluates USN fighter and attack aircrew attitudes with respect to requisite crew complement in six critical mission areas. This chapter presents an outline of how this evaluation is conducted in the form of a problem statement, a research question, and investigative questions with

accompanying hypotheses. Following this outline, the scope and limitations of the research are addressed.

Justification of Research

Military aircraft have undergone a puzzling evolution since their first operational employment in World War I. In this evolution, issues such as size, speed, cost, maneuverability, and crew complement have been critical considerations in establishing a final design. We have seen changes from small to large to small; subsonic to supersonic to subsonic; and single- to multi- to single-seat. Examining this evolution and attempting to explain the objectives, constraints, and resulting design choices would be a formidable task. Such an explanation, while interesting, is really unnecessary as the primary focus in aircraft development has remained unchanged: The real goal is simply to provide the optimal design to accomplish a stated mission given the resources available. While the primary focus has remained unchanged, new technology places new demands on our scientists and engineers. No longer are the majority of the efforts directed primarily towards higher-faster-farther. Issues such as detectability, weapons integration, precision navigation and targeting, and human factors considerations all are weighed heavily in the design process (Cryer, 1990:1-6).

For fighter/attack aircraft, no issue generates more controversy than that of whether to design one- or two-seat aircraft. Despite this controversy, there is a surprisingly small number of specific studies

addressing this issue as it pertains to these combat aircraft. One study that does address this issue attributes this lack of data to decisions regarding crew configuration being made primarily by "economic and political factors" (Crawford, undated:1). It is beyond the scope and not the intent of this research to assess the validity of Crawford's claim. It is important, however, to acknowledge that issues such as individual service priorities, historical precedent, and funding considerations no doubt play a large role in the acquisition of all major weapons systems.

Department of Defense and individual service priorities play a key role in the attention a system (aircraft) receives. If a particular mission area is viewed as being of increased importance, the systems that are effective in accomplishing that mission are given a high priority. Funding of a particular system is tied to both its ability to perform critical missions and political considerations. Competition for limited funding both across and inside services has often served to fuel a debate on relative capabilities and associated costs. This competition is not limited to funding for new acquisitions. Funding for upgrades and modernization of existing systems is also involved.

Further complicating the issue is the difficulty in measuring the actual cost of a weapons system. A less expensive system may be less expensive only in the short term. In the long term, added effectiveness can far outweigh potential short term cost savings. Alternatively, a more expensive system may not relate directly to long term cost savings via added effectiveness. This dynamic relationship between cost and

performance is a major driver in most design decisions (Gill,1993:1-7). In the final analysis, cost must be balanced with performance to ensure aircrew members are afforded survivable and mission effective aircraft to accomplish the missions they are tasked to fly. This research focuses on the performance aspect alone of the one- and two-seat discussion.

Aircrew Workload, Crew Coordination, and Technology

Air combat has become increasingly technical in nature. Today, fighter and attack aircrews must process and weigh a myriad of mission critical information: precise navigation data, complex threat warnings, target acquisition information, fuel/engine/aircraft status updates, and other mission essential elements. The requirement to incorporate this information into decisions made in the cockpit has led to increased workload for the aircrew. This increased workload in some more demanding mission areas has resulted in the requirement for an additional crew member. The role of this additional crew member varies depending on the mission. In some cases the additional crew member is an information provider only. In other instances the crew member operates as both an information provider and decision maker. At issue today is whether technology can provide information and aid in decision making to allow a single crew member to effectively execute the mission in question. The demands of the combat environment associated with these Fighter/Attack missions serve to further complicate this issue. Of 34 aircraft accidents in Red Flag exercises (simulated combat

conditions), over two thirds of these were attributed to "controlled flight into terrain" (Kitfield, 1989:37). This statistic is representative of how even a pilot's top priority (flying the aircraft) can be ignored in a high stress/high workload environment. These accidents serve as grim reminders of the demands combat can place on aircrews.

This crew complement issue cannot be viewed from a workload perspective alone. The issue of crew coordination and its effect on performance must be considered. There are some who believe having two inputs and two decision makers in a combat situation can cause confusion and costly delays in decision making (Eyler and Ward, 1986:21). A number of one-seat USAF pilot comments reported in a study of USAF pilot attitudes regarding the crew complement issue support this claim. Interestingly, in the same study, this view was rarely reported by two-seat pilots. (Starr and Welch, 1991:App B).

Crew coordination as it relates to task saturation is certainly an important consideration. Adding crew members to compensate for increasing workload is not necessarily the solution to all problems. Certain tasks in complex missions can be delegated, but others cannot. A bombardier navigator providing targeting data to an A-6 pilot flying a night low level is often crucial to mission success. If the bombardier is to be replaced in an upgrade to the A-6, technology must be able to provide this, and other information the bombardier provides, in a useable manner, to the pilot.

Considerable attention is being focused on cockpit design for our next generation aircraft in an effort to cope with increased complexity and its effect on workload. While this attention is welcome, there is evidence to suggest that our current aircraft are still not user friendly. "Experts concede that while both the aircraft's and the pilot's jobs have steadily become more complex, cockpit design has remained fundamentally unchanged" (Kitfield, 1989:39).

Beyond original design considerations, there is concern that the dynamic nature of technology itself will make it difficult to limit aircrew task saturation through human factors improvements. Upgrades to aircraft that give added capability can also represent an increase in the required workload to operate them. The increase in workload is associated with the difficulties inherent in integrating the newer technology into the existing system design. The "added capability" these upgrades afford is considered to outweigh the increase in required workload.

Largely due to increased time to procure and prohibitive cost, there are a number of combat aircraft in service today with 30 to 35 year old designs, like the A-6E, B-52, and F-111. Multiple airframe and avionics upgrades to their original designs have kept these aircraft survivable and effective. It is apparent that future aircraft will be even more cost prohibitive and therefore also likely to face a lengthy time in service.

Combining this dynamic nature of technology with anticipated long aircraft service lives, it is reasonable to assume our next generation

combat aircraft will also require periodic upgrades. While designed pre-planned product improvements (P^3I) and attention to system growth requirements serve to minimize this integration issue, it nonetheless is an important consideration from a workload perspective.

There is little doubt that in some missions new technology can and will adequately replace a crew member in the cockpit without sacrificing either mission success or survivability. The navigator duties on low intensity airlift missions can likely be replaced by the highly reliable global positioning system (GPS), for example. Crew member replacement is less clear, however, when looking at fighter/attack missions that have been primarily executed by two-seat aircraft. The night/all-weather attack mission is perhaps the best example of a mission where two crew members have been traditionally considered a requirement.

The complexity of the one- and two-seat discussion is evident. As mentioned, there are few specific studies specifically examining it. This research provides an all important perspective from an all too often neglected source, the operators. With responses by 290 pilots and NFOs actively flying, a large percentage with significant flight and combat experience, the information could be extremely valuable.

Specific Problem Statement

The purpose of this research is to collect and analyze USN aircrew inputs to assess their perceptions regarding the ability of new cockpit and aircraft technology to replace the Naval Flight Officer without compromising survivability or mission effectiveness in a combat

environment. A definition of mission effectiveness includes elements of survivability and success. This study will use these two elements to measure mission effectiveness. Success is defined as the literal completion of the assigned mission (i.e., bombs on target). Survivability is defined as the ability to operate in anticipated threat environments and return to base. This USN study is a follow-on effort to a similar study of USAF pilots conducted in 1991 by Starr and Welch, a previous team of AFIT students. While structural differences between the two studies exist, they share a common purpose. Where possible, a comparative analysis is provided to lend credibility and strengthen the content validity of both studies.

Research Question

Directly in line with the purpose of this study, the research question is: Do USN aircrews believe new cockpit technology can replace the need for Naval Flight Officers (NFO) in future USN combat aircraft? The selection of this research question represents an attempt to narrow focus and not an attempt to assess current capabilities via implicit assumptions. The survey instrument was designed to reflect this narrow focus. The respondents are not limited in their ability to question current aircraft assignment by mission. For example, it is not assumed that two seats are required for any particular mission given the current generation of aircraft. The same methodology is evident in the selection of investigative questions and their associated hypotheses.

Investigative Questions and Hypotheses

1. To what degree is survivability affected by crew complement?

Hypothesis: The presence of an NFO will not affect survivability.

2. To what degree is mission success affected by crew complement?

Hypothesis: The presence of an NFO aboard will not affect mission success.

3. What effect will new technology have on aircrew workload?

Hypothesis: Technology will serve to decrease aircrew workload.

It is important to realize that the selection of hypotheses is a statistical requirement and does not reflect a bias towards any particular response. As stated earlier, it is expected that the responses will vary by mission area and demographically by respondent. The intent of this research is to detect, categorize, and analyze this variance.

Scope and Limitations of Research

This study uses a representative sample of fighter/attack pilots and NFOs actively flying USN combat aircraft. Aircrew from F/A-18, A-6E, EA-6B, and F-14 squadrons were sampled. Acknowledging that valuable input can be gained from aircrew members flying other Navy aircraft, a desire to have a homogeneous sample (fighter/attack combat aircrews) determined the target population. The potential for bias when surveying NFOs on this issue is a consideration. The NFOs are being asked to assess the importance of their own role in the cockpit. Their input, however, is necessary as they represent a large part of the

corporate system knowledge in some of these aircraft and therefore provide valuable insight. In any case, the large sample size facilitates categorical analysis that can detect any such bias. In addition to categorizing respondents as NFO or Pilot, other comparisons are made. Flight time, combat time, and special qualifications held were also used to categorize responses.

A primary concern of this research is the combat environment. There are a limited number of combat experienced aircrew. Further,in most cases their combat experience was acquired in a single conflict, Operation Desert Storm. Statistical analysis can detect any significant deviations between combat and non-combat experienced aircrew.

Finally, and perhaps most significantly, any conclusions developed in this research are determined by correlation of individual inputs. These inputs are based on a perception of new technology and not on a scientific study of that technology. Essentially, aircrews were asked to assess the effect of new technology based on how recent technology had influenced their respective aircraft and mission. The researchers did not provide these aircrew with specific examples of next generation technology. Any effort designed to educate them on the issues ana developments of technology was viewed as potentially introducing bias into the sample.

Summary

This chapter has identified a part of the overall management problem the military faces in developing and employing current and

future aircraft. The complexity of this crew complement problem is evident, and the limitations of using aircrew perceptions acknowledged.

The true and final test of any aircraft is its employment in combat. Any postulation based on theory and historical data is, at best, educated guess work. Nonetheless, "educated guess work" is necessary and any relevant data properly gathered and structured will improve the probability of an accurate forecast. It is critically important that the crew complement issue and others like it are made from an objective frame of reference. Survivability and the literal completion of the assigned mission (success) cannot be ignored. This study attempts to provide an objective and critically important piece to the puzzle. This research deals with operational effectiveness and survivability.

II. Literature Review

Introduction

This chapter reviews background literature pertinent to the research area. The primary thesis objective is to gather and analyze USN aircrew data regarding crew configuration for USN combat aircraft. Ultimately this analysis could be used as an input for Department of Defense decision-makers in assessing potential crew requirements of military aircraft by mission area. This determination is important not only in deciding the most effective configuration for the design of our aircraft, but, also as an aid in employment of combat aircraft.

In chapter one, the military management problem in the context of the one- and two-seat issue was presented. A number of factors affecting this issue were also presented. This chapter will provide additional background in support of these factors impacting the one- and two-seat issue. As mentioned in chapter one, few specific studies are available to aid in this effort.

The literature review is divided into two categories. The first category is general human factors in aviation. In this section information relevant to cockpit workload and crew coordination in general is presented. Following the human factors section, a section detailing specific studies dealing more directly with combat aircraft is presented. Finally, a summary of information presented is provided.

Human Factors in Aviation

The bulk of information in this area deals with human performance characteristics under varying amounts of stress and workload. According to Weiner and Nagel, "The human is most reliable under moderate levels of workload that do not change suddenly and unpredictably" (Weiner and Nagel, 1988:158). Military flying is, by nature, dynamic and often filled with unpredictability. Flying in combat only serves to exacerbate this phenomenon. Given the desire to moderate workload, it must be shown that in either the one- or two-seat configuration information can be processed and decisions made without task saturation. Do some high workload missions require two crew members for optimal execution, while others lend themselves to one-seat operations? If the aircrew attitude research can demonstrate a variance between mission types, it can suggest which missions are best suited to a particular configuration.

For the one-seat mission, every task in the aircraft is either performed by an on-board system or the pilot. Because of time requirements, task prioritization is a critical element from a survivability perspective. During routine phases of flight, it is not difficult to prioritize correctly. However, as workload increases, the pilot's primary duty of flying the aircraft can be challenged. "The military pilot is essentially a programmer, monitor, decision-maker, and systems manager" (Weiner and Nagel, 1988:451). In the pilot's effort to manage time wisely, secondary tasks may be accomplished less efficiently as difficulty increases (Weiner and Nagel, 1988:175-176).

While advances like autopilot functions and sophisticated navigation equipment have eased the pilots' workload, "there is considerable evidence to suggest that increased automation may exacerbate the potential for problems in certain situations" (Weiner and Nagel, 1988:337-338). "By reducing workload and providing precision information processing, on-board computers have eliminated many sources of crew error, but they have simultaneously increased the subtlety of error detection" (Weiner and Nagel, 1988:340). This trade-off between reliable, highly precise aircrew aids must be balanced with effects such as this "subtlety of error detection." When one combines the difficulty of detecting a subtle error with the demands of low-altitude/high-speed flight, the potential for disaster may increase significantly.

A quick look at Air Force accident statistics demonstrates the demands associated with tactical flying. Of more than 100 jet fighter crashes in FY 1987, the Air Force estimates that two-thirds of them were due to pilot error. The category "controlled flight into terrain" now accounts for a greater percentage of accidents than ever before (Kitfield, 1989:34). We may never know the exact causes of these accidents, but indications are that they were due, at least in part, to task saturation (Kitfield, 1989:34). In other words, during a critical phase of flight, the pilot likely misprioritized his tasks and flew a functioning airplane into the ground. It is conceivable that a large number of these accidents could have been avoided had there been another crew member aboard.

Automation has its place, but when instrument after instrument is added to today's modern fighters, the resulting information overload can sometimes overwhelm the pilot during high-task missions. In fact, one study indicates that to reduce the cockpit "noise" level, "even the most experienced pilots routinely admit that they turn off the aircraft's warning and information systems in stressful situations to avoid becoming hopelessly confused" (Kitfield, 1989:34). A number of USAF pilot comments received in the Starr and Welch study further support this position (Starr and Welch, 1991:App B). For some, the current generation of combat aircraft is "a culmination of a thirst for high-technology sophistication and performance that was rarely tempered by human-factors concerns" (Kitfield, 1989:34). "As more and more systems were integrated into the airframe, little thought was given on how best to display that information to the pilot" (Kitfield, 1989:39). Designers must pursue at least two alternatives. The first, as suggested by Kitfield, is to pursue ways to more effectively present information to the pilot so he/she can retain the highest degree of effectiveness. The second alternative is to demonstrate whether or not it is possible to use technology to replace the systems officer.

Jones and Pisano, studying advanced navigation technology and artificial intelligence, found that a next-generation navigation suite can prove to be highly effective in a tactical environment. A drawback, however, is the disproportionate amount of time required of the flight crew in monitoring the system (Jones and Pisano, 1984:1-1). Despite the high degree of automation inherent in the proposed system, the study

indicates that during high workload missions, it may be prudent to have a systems expert on board.

An early 1980 study conducted by Taylor of Boeing Aircraft Corporation reviews the crew complement issue. The study was performed at a time when the 757 and 767 designs were under development. In his study, Taylor found that among airliners with two- and three-person crews, the two-person crews had a significantly better safety record in all areas (Taylor, 1980:4). There were a number of potential confounds associated with the data. The design of the two-seat aircraft was of course different from that of the three-seat aircraft. A key point in the study stated that "the total time spent doing observable tasks was approximately 25 percent of each crew member's available time" (Taylor, 1980:1). This data may suggest that airline flight deck personnel are being worked below the moderate level mentioned by Weiner and Nagel. Some military missions, like their airline counterparts, may also require fewer crew members. However, if one directly compares the cockpit work load required of a typical commercial airline flight with that of an F/A-18 pilot on a night low-level in marginal weather, a marked difference in work load would be realized.

Tactical Studies and Simulations

Turning away from human factors, specific simulation and academic studies of this complex issue will be examined. The following studies focus on tactical scenarios.

Given the importance of this issue, one would think there would be a considerable number of studies available specifically comparing one- and two-man cockpits. In fact, as mentioned, only a few studies directly address this issue. While few studies directly address crew complement, there are a number of studies which cover information relevant to it.

There are a number of mission areas where technology is being considered (and utilized in some cases) as a replacement for crew members. Perhaps the most controversial of these is the night air-to-ground mission. This controversy is highlighted by the aggressive development of a night air-to-ground capability for single seat fighters in both the U.S. Navy and Air Force. In his study of "One Versus Two Seat Fighter Aircraft," Crawford points out a number of distinct advantages for each configuration (Crawford, undated:8). The advantages cited support a two- seat configuration for more complex missions and find two-seat aircraft more survivable in all scenarios. One-seat aircraft, on the other hand, generally have better aerodynamic performance and lower life cycle costs.

As alluded to above, a greater number of missions are being performed single-seat or with fewer crew members than previously. An example of the current trend toward crew reduction is the Air Force's C-17. Its crew will not include a navigator. A short article that appeared in <u>Air Force Times</u> describes the evolution of navigation and its role in aviation as "having come full circle" (Callandar, 1990:69). Callandar describes how technology, specifically instrument navigation

system (INS) and global positioning system (GPS) advances, has made navigation possible for the two-person crew on transport missions. While using a highly reliable space-based navigation system to replace a crewmember sounds plausible for less complex missions, there is still considerable disagreement among the current crews of these aircraft as to whether this change is wise (Starr and Welch, 1991).

In 1985 the Center for Naval Analysis (CNA) conducted a study to compare a one-seat F/A-18 with a two-seat version (Ward and others, 1986:1). Using the Manned Air Combat Simulator, operated by McDonnell Aircraft Company and U.S. Navy flight crews, CNA examined a number of the F/A-18 potential mission areas. The two-seat crews performed better across five different missions flown at varying threat levels, with a level of significance of .07. Interestingly, the two-seat crews did not score significantly better in the night attack mission, while the single-seat crews actually performed slightly better in the adverse weather attack scenario (Ward and others, 1986:26). The study does provide statistically significant data to substantiate the overall better performance of two-seat crews over a single pilot for all combinations of threats and mission areas. While the above study seems to conclude that one would be better off employing two-seat aircraft in all scenarios, it may be misleading. The rankings were based on a composite of a number of survivability and success categories. In fact, one-seat crews, as mentioned, actually performed better in some specific areas.

General Dynamics (GD) conducted a study in 1987 of the F-16 in a reconnaissance role with both dual and single seat cockpit configurations (General Dynamics, 1987). Crews were tasked to fly a medium-low-medium altitude profile in search of high-value second-echelon targets. The threat scenario was designed to prevent total threat avoidance. The study's conclusion was that for the night, high threat scenario, a two-seat configuration was recommended. This recommendation was minimized by a suggested design improvement that could allow single seat operation (General Dynamics, 1987:iii). It is noteworthy that CNA and GD came to different conclusions regarding the night, high-threat mission. It is likely that CNA provided a different threat scenario from GD and that the CNA scenario made it possible to more easily avoid the threats.

Vice Admiral Robert F. Dunn (Retired), a former Commander of Naval Air Forces for the Atlantic Fleet, describes how available technology has made a single seat replacement for the Navy's F-14 a possibility. Vice Admiral Dunn states that:

> In fly-by-wire aircraft the physical effort of control manipulation is all but removed from the pilot's schedule. Heads-up displays fed by a wide spectrum of both external and internal sensors and digital communications links can present an incredible amount of information. The most important of that information can be sorted out by even the most rudimentary form of artificial intelligence. Inertial navigation systems, global positioning systems, radar, forward looking infrared, and moving map displays make navigation a piece of cake (Dunn, 1991:13).

While Vice Admiral Dunn appears to be a vocal supporter of technology replacing the backseaters in the F-14, he later recommends that the Navy help the displaced backseaters transition to the A-12, the

E-2 and the S-3 (other Navy aircraft). The A-12, at the time of publication of this article, was the Navy's scheduled replacement for the A-6 (the Navy's primary night/all weather air to ground aircraft). Vice Admiral Dunn either chose not to address the single/dual issue of the A-12 in this article, or believes this mission warrants the additional crewmember. In addition to the performance issues, Vice Admiral Dunn mentions that the cost of two seats is becoming prohibitive when compared to the cost of single-seat operations (Dunn, 1991:13).

CNA, in addition to the simulation studies, published a study of the cost and personnel issues associated with a two-seat F/A-18 (Marcus, 1986). Marcus observes that "even though personnel costs of manning the dual-seat aircraft may be the largest single expense, the additional maintenance costs incurred over the life of the aircraft may be significant" (Marcus, 1986:9). This and other cost analyses serve to suggest that costs associated with adding an additional crew member are significant. The benefits of additional crewmembers must therefore warrant the additional cost. One justification of the added costs may be that the additional crew members, in the long run, will serve to reduce overall costs in the form of a lower loss rate due to avoidable accidents. In such a case, any personnel cost reduction noted would be a false one.

<u>Summary</u>

The contents of this chapter have demonstrated the need for further research in the area of crew requirements. While the literature

review has not been exhaustive, it appears that there is not an abundance of specific information revealing how to best build U.S. aircraft from a crew size perspective.

There appears to be evidence to support that Crawford was on target with his hypothesis (referenced in Chapter 1) that crew size is driven primarily by cost and political factors. This possible political influence would, in part, explain the lack of specific information available. Given current budget constraints, cost is definitely a significant factor in aircraft design. The development and procurement costs of combat aircraft have doubled every four years since World War II (White, 1974:6). Crew configuration is a major design consideration, and must be accurately assessed early in the design process. The later in the design phase major changes are made, the more costly these changes become (Andrews, 1992). This research indicates that the workload associated with some missions may require priority be given to crew size considerations. Mission success and survivability are, in the long run, cost effective.

III. Methodology

Introduction

This research addresses pilot and Naval Flight Officer (NFO) attitudes regarding crew complement requirements for various combat missions given the current and future states of technology. The current state of technology is based on capabilities existing in the respective aircraft the respondent flies. The future state of technology is based on an individual perception by each respondent and will likely vary from person to person. This variance across the population is random and therefore, given the large sample size, any errors introduced would also be random.

The data collected for this thesis is not technical in nature. This data was gathered via survey and statistically analyzed for commonality and convergence with respect to the role of the NFO and technology. Specifically, the possibility that technology can and will be able to replace the NFO in certain missions was investigated. It is intended that the results of this study be used as an input to the solution process as new aircraft are developed for the armed forces.

This chapter outlines the plan of attack for data collection and analysis. The following areas are addressed:

1. Research Design,
2. Target Population,
3. Sampling Technique,
4. Data Collection,
5. Instrument Development, and
6. Data Analysis.

Research Design

The design of this research is similar to a study of USAF pilots completed in a previous thesis. (Starr and Welch, 1991:Ch 3). Starr and Welch measure attitudes of active USAF pilots flying all types of fixed wing aircraft. In both efforts, survey data of USAF and USN pilots and systems officers is analyzed to provide a user-level operational input. With the permission of Starr and Welch, actual survey data from their 1991 thesis will be adapted for this study to compare USAF inputs to USN inputs. An assessment was made, by mission area, of U.S. Air Force pilot perceptions on the feasibility and resulting impact of replacing the USAF Navigator, Weapon System Operator, and Electronic Warfare Officer (NAV/WSO/EWO) with advanced technology.

The Starr and Welch thesis had a slightly different focus from that of the current study. Their research objective was to "gather sufficient data from six different Air Force pilot groups to assess whether the NAV/WSO/EWO can effectively be replaced by cockpit automation technologies on various combat aircraft" (Starr and Welch, 1991:1-11). To answer their research question, they investigated a number of more specific areas. One of these was an analysis by mission area, which directly supports the current research objectives. A similar survey of U.S. Navy pilot and NFO perceptions will be conducted in this study.

This USN study was expanded to include both pilot and naval flight officer (NFO) responses, but narrowed to cover only aircrew flying four specific aircraft. These "four specific aircraft" represent the

tactical air combat arm of carrier-based aircraft. The four Navy aircraft these pilots and NFOs fly are the F-14, F-18, A-6, and EA-6. Many of the same issues investigated in the USAF study are investigated in the USN study. A qualitative comparison of the two studies will be conducted in chapter five.

The survey instrument measures attitudes of pilots and NFOs with respect to survivability, mission success, and aircrew workload. These three parameters are evaluated by the aircrew in the context of both current technology and perceived future technologies across six mission areas. The six mission areas covered are:

1. Air superiority,
2. Close air support,
3. Low/medium threat interdiction,
4. High threat interdiction,
5. Night/all weather interdiction, and
6. Suppression of enemy air defenses (SEAD).

These six missions are missions that USN carrier based aircraft are typically asked to execute. While other relevant mission areas exist, these six are believed to be more demanding and provide breadth of coverage. Not all aircrew members surveyed perform all six listed missions. Despite this potential lack of a broad experience base, responses were solicited from aircrews from all four aircraft in all six mission areas. Direct questions in the survey concerning the aircrews' perception of their respective aircraft's capability are used to determine the relative importance for categorical analysis and comparison. Responses of "not applicable" were allowed in the event a crew member felt his aircraft had no capability in a particular mission.

The survey contains three distinct sections. The first two sections gather data in support of answering the research and investigative questions. The third is a demographic data section that facilitates categorical analysis. Before addressing these three sections in further detail, the specific independent and dependent variables measured are presented.

There are 54 questions in section I and II of the survey. There are three dependent variables that directly relate to the research and investigative questions: mission success, mission survivability, and aircrew workload. Mission success and survivability are mission effectiveness factors used to answer the first two investigative questions. These two mission effectiveness factors are measured against four independent variables. The independent variables are mission flown, aircraft type, crew configuration (one- or two-seat), and technology (current or future). The dependent variable aircrew workload is measured only in the future context. It is measured against technology and mission flown in this future context. This independent/dependent variable structure is evident in the following three sections.

The first section will assess attitudes about single-seat and two-seat operation for the aircrew's current aircraft (i.e., given current technology) in the six mission areas. The second section places the aircrew in a future context and measures perceptions about the next generation tactical aircraft in the six mission areas covered. The survey measures the perceived effects of an NFO in the next generation

combat aircraft by exploring perceived mission success rates and survivability rates. This section also includes an additional question for every mission designed to measure the aircrews' perception of technology as it relates to workload in future aircraft. Finally, a third section collected demographic data including rank, aircraft type, crew position, time in aircraft, total flying time, total combat time, instructor time, and special qualifications held. The demographic data was collected to compare results across categorical boundaries. This categorical comparison is critical as a number of potential confounds present themselves if the population is treated as completely homogenous. The categorical analysis and justification is addressed in detail in chapters four and five.

In this vein, data was measured from several categorical perspectives. The specific categories the data were divided into are addressed later in this chapter and in more detail in Chapter 4.

Population

The total population in question for this study includes aircrew currently on active duty in the US Navy assigned to six selected non-deployed airwings. As previously mentioned, only A-6, F-18, F-14. and EA-6B aircrew members were surveyed. The population was limited in an effort to increase relevance. Additionally, no attempt was made to survey aircrew who were not in a sea rotation operationally flying. In other words, only active flyers were surveyed to exclude rated personnel in support billets. While selection of this population eliminates a

number of potential respondents with significant experience, it ensures uniformity of sample and minimizes time-biased distortions.

There are currently 11 active airwings in the Navy. Each airwing typically contains two F-14, two F-18, one A-6, and one EA-6 squadron. F-14 and A-6 squadrons typically contain 16 pilots and 16 NFOs. F-18 squadrons contain 16 pilots. The EA-6 is a four-place aircraft crewed by one pilot and three NFOs (each of their squadrons typically contain six pilots and 18 NFOs). Additionally, airwing staff officers in an active flying capacity were surveyed (approx 6 to 8 per airwing). Using these criteria, the relevant population summarized in Table 1 was created. With a total population of approximately 1771, obtaining a sample large enough to be representative was not difficult.

TABLE 1

RELEVANT POPULATION (BASED ON 11 ACTIVE AIRWINGS)

AIRCRAFT	PILOTS	NFOs	TOTAL
F-14	352	352	704
F-18	352	-	352
A-6	176	176	352
EA-6	66	198	264
CVW Staff	66	33	33
TOTALS	1012	759	1771

<u>Sample</u>

Despite the relatively small population, surveying the Navy has some inherent obstacles in obtaining a representative sample. At any given time, approximately three airwings are deployed at sea. These

deployments effectively cut the available population by about 25%. Other airwings are in various stages of their respective operational schedules and are not available for survey. Additionally, it was desired to obtain an even split between West and East coast respondents to minimize any geographic bias. Given the above constraints, six airwings, three East and three West, were targeted.

Surveys were sent to the all squadrons operating the four aircraft of interest. Sufficient numbers of surveys were provided to allow for a complete response by all pilots and NFOs assigned to a particular unit. No attempt was made to compensate for variances in manning. Additionally, temporary assigned duty requirements and unit detachments are acknowledged as potential sources of negative response. Surveys were also mailed to the six airwing staffs to allow response by experienced aviators assigned to the staff.

Surveys were mailed in a package to respective airwing and squadron operations officers for distribution to individual respondents. Each wing and squadron package contained a cover letter detailing specific instructions for distribution and completion (reference Appendix B). Emphasis was placed on the importance of experienced personnel responding in order to inject a desirable experience bias, which serves to lend credibility to the sample.

In total, 948 surveys were mailed out. With 285 responses, a response rate of 30% was realized. With a sample base of over one-sixth of the total population, a representative sample was obtained.

Support was solicited from the squadrons' senior leadership to emphasize the importance of the survey. Distributing the surveys through the respective chain of command (vice mailing the surveys directly to crew members on a by-name basis), may have resulted in a degree of personal rapport being lost. This loss of rapport was offset by the added accountability inherent in using the chain of command. In any case, obtaining a roster of active duty fliers by airwing would have been a formidable administrative task.

With so many potential categories to analyze, a large and diverse base for each category was necessary to draw confident conclusions. By targeting approximately 60% of the available population uniformly, and assuming an equal amount of participation from each coast, our data reflected the fleet in proportions similar to those that actually exist. Given the voluntary nature of the survey, no effort was made to track response rate by unit. However, contact by phone ensured each wing staff or squadron received its respective package. It was assumed that if the surveys were received, the response rate by unit would be uniformly distributed.

Data Collection

A major consideration for this survey was collecting the proper data. In order to obtain the right data, the right questions had to be asked. At the same time, an effort was made to keep the length of the survey manageable. The larger the number of variables measured, the more questions asked, and consequently, the larger the survey. In this

research, the dependent variables are mission success and survivability. These two areas can be combined to assess mission effectiveness on an overall basis. The variables chosen as independent variables for the purpose of this research are crew complement (whether or not an NFO is part of the crew) and technology as it relates to workload. The effects of the independent variables on the dependent variables were measured across the six mission areas already mentioned.

Mission success is defined as the literal completion of the assigned mission. For interdiction, "bombs on target" is a good example of this construct. Survivability is defined as the ability of an aircraft to successfully launch, operate in the hostile environment of the assigned mission, and return to base without loss of life or the aircraft.

Data was collected using a five-point Likert scale (Emory and Cooper, 1991:220). Statements were presented to the subjects in declarative sentence form. The subjects responded on a scale ranging from strongly agree to strongly disagree. The statements themselves measure only one relationship at a time. For example, given an air superiority role, respondents were asked whether or not their mission can be successful single-seat. For comparative purposes, the same question was posed from the viewpoint of two-seat operations. A separate set of questions measuring these two dependent variables with respect to survivability in the air superiority role followed. In the second section of the survey (future technology), respondents were additionally asked to respond to a fifth question. This question

measured their attitudes regarding the effect of technology on aircrew workload. All of these questions were posed across the six mission areas.

The first section of the survey considers performance from an aircraft-specific point of view. While perhaps unrealistic, aircrews were asked to respond for both single-seat and two-seat variants of their respective aircraft across all six mission areas. While two-seat crews gave opinions about single-seat operations and vice versa, respondents were directed to assume present aircraft capability in general. The single-seat pilot answering the two-seat question was asked to assume that his aircraft was hypothetically transformed into a two-seat version with a workable division of labor between the pilot and NFO. For the two-seat crew answering the single-seat question, the aircraft maintained the same capabilities, but all systems controls were considered accessible to the pilot. The challenge here was to minimize bias by having crew members analyze their roles from a competing position. A measurable amount of bias is expected, but these perceptions are useful.

The second section attempts to evaluate future performance based on a next-generation combat aircraft perspective. All respondents were to assume that the single-seat version would be optimized for single-seat operations, and the two-seat version would be optimized for two-seat operations. Given state-of-the-art technology, respondents assessed the role of NFO across the same six mission areas. The section

also contained questions designed to measure the respondent's perceptions of workload increase/decrease with new technology.

Through analysis of the collected data, the researchers present a continuum of mission success and survivability along the lines of the six mission areas. The ultimate objective is to develop a hierarchy of mission difficulty and possibly define a point where required workload builds to a point where a multi-place aircraft would be required.

The primary focus of this research is to compare single-seat and two-seat operations. The EA-6B is a four-place aircraft. No quantitative attempt was made to evaluate the crew size of that aircraft. EA-6 responses are considered useful, however, when measuring attitudes about the role of pilots and NFOs in combat aircraft in the future.

The survey packages were distributed by first-class mail. Each package contained the entire unit's complement of surveys to include questionnaires, optically-read scan sheets, and a self-addressed/stamped return envelope for each respondent. The materials provided to the respondents should have made responding to the survey easy.

Instrument Development

Much of the instrument development process was previously discussed in the data collection section. This section will explore the subject in more depth detailing the process of moving from a managerial perspective down to the individual measurement questions. The instrument was developed by following a process described by Emory and

Cooper (1991: 348-353). Their question hierarchy provides the framework for instrument development. Specifically, the questions are:

> 1. The management question--that problem which the manager must answer.
> 2. The research question--that basic information question or questions which the researcher must answer in order to contribute to the solution of the management question.
> 3. The investigative question--those specific questions which the researcher must ask in order to answer the research question. Within this level, there may be several questions as the researcher moves from the general to the specific.
> 4. The measurement questions--those questions which respondents must answer if the researcher is to gather the needed information. (Emory and Cooper, 1991: 348-353)

The remainder of this section will explore the development and criteria used in selection of the measurement questions used in the instrument. The goal for the measurement questions is to identify an idea or construct in the body of the question, and measure the degree to which the respondent agrees or disagrees using the Likert scale. To minimize the total number of questions on the survey, each question had to exhibit two characteristics: (1) it had to be relevant to the research, and (2) it had to reflect a favorable or unfavorable position on the attitude in question (Emory and Cooper, 1991:220).

An important concept in dealing with Likert scales is that of consistency. One of the most reliable methods of ensuring consistency and establishing validity in the survey instrument is to pretest it (Emory and Cooper, 1991:376). Time constraints unfortunately did not allow for a formal pretest. A limited number of surveys were, however, reviewed by several AFIT students. Without a formal pretest, care was taken to ensure that questions were as unambiguous as possible and that

no unnecessary communication problems due to jargon or phraseology existed. The survey was approved through formal channels at AFIT and through Navy Survey Control. Comments were solicited from all levels and the survey was modified accordingly. Appendix A contains more information about the approval process necessary for surveying the U.S. Navy.

Another area addressed was the content validity of our six mission areas. On the surface, air-to-ground missions appear to be adequately identified while air-to-air missions are lumped into one general category. While it is true that elements of the air superiority mission such as lane defense, point defense, high value air asset protection, and fighter escort each present unique problems, each mission possesses similar requirements from a crew coordination/flight coordination perspective. Too narrow a definition could potentially present problems in the analysis of data. The categorizations of low/med, high, and night/all weather interdiction, however, were not optimal. The fact that some night missions can be low threat and some day missions can be high threat could have contributed to some confusion. The intent was to compare attitudes by threat and to specifically measure the night/all weather mission as well. While no comments addressing this potential ambiguity were received by respondents, differing individual interpretations with regard to this issue must be acknowledged. In the final analysis, the terminology used was familiar to the aircrew surveyed and interpretation errors with respect to mission areas selected is regarded as minimal. The six missions described previously

are considered a complete enough list to adequately measure aircrew attitudes across a wide spectrum of operational conditions.

Four questions per subject area are required to adequately measure all relevant variables. The six missions, combined with the four questions per mission, generate a minimum of 24 total questions, not including demographic questions. Because present and future attitudes were measured, the new total comes to 48. Finally, the six workload/technology questions bring the total to 54. It was thought if the survey were too long, response rate would have suffered due to lack of interest or short attention span. On the other hand, a predictable style might lull the respondents into a mechanical response mode. Every effort was made to keep the survey interesting.

Analysis

Data analysis was divided into three major sections. All three sections are designed to measure responses by mission type. The analysis methodology for all three sections is consistent.

The first section contains information about current operations. The first 24 survey questions are analyzed in this section. Because of the limiting nature of these questions with regard to aircraft-unique qualities, very little cross-category analysis was done.

The second section measures perceptions about future aircraft operations. Questions 25-54, excluding the six technology/workload questions, are analyzed. Because of the common focus of a "next-

generation" aircraft, extensive cross-category analysis was performed in addition to the like-aircraft analyses.

The third major section focuses on the technology-workload relationship. This section also contains a detailed within-category and cross-category analysis. The next few paragraphs explain some of the particular techniques involved in the data analysis process.

As stated in the data collection section, several approaches to analysis were made. First, an absolute assessment of opinion by category analyzed is made relating the role of single-seat to two-seat operations by mission type. Aircraft-specific perceptions, both combined (pilot/NFO) and separate are then compiled. Next, perceptions based on rank and/or experience level are generated. And finally, an overall "Navy opinion" regarding single-seat and two-seat operations is provided. Following the overall assessment of opinions by community, the researchers analyzed differences of opinion (sample means) between groups by creating 90% confidence intervals from respective population means, standard deviations, and sample sizes. These confidence intervals represent a 90% probability that the overall population of a specific category forms a specific collective opinion on the issue measured. For example, if on the 5-point Likert scale (1 meaning strongly agree and 5 meaning strongly disagree), F-18 pilots responded to the single-seat air superiority success question with a mean response of 2 ,a lower confidence interval limit of 1.8 and an upper limit of 2.2, the population as a whole agrees that single-seat air superiority

missions can be successful. One can further state with a 90% confidence level that the population mean is between 1.8 and 2.2.

One advantage of this technique is that one could graphically display any data point and visually compare responses both within-category and cross-category. Overlapping confidence intervals for two questions would indicate that the two data points generally are statistically equal or at least have little difference of opinion. Data points which do not overlap suggest that the two responses are statistically different and that the opinions are truly different.

The above description represents a graphical means for performing two-sample t tests of the data. In addition to the graphical method just described, select statistical testing (paired and two-sample t tests) will also be accomplished using specific mean and variance data. The graphical data will reinforce the statistical tests. All tests will be accomplished using a 90% confidence level or an α of .10.

Data was carefully studied both within and across communities for indications of divergence. Chapter 4 contains the detailed analyses along with selected supporting graphics and statistical test results. Mean, standard deviation, and sample size data are contained in tabular format in Appendix C. Because of limited resource availability and time constraints, it was futile to compare every data and sub-data group to every other group. An attempt was made, however, to rank the mission types by workload and order of complexity in an effort to identify in an ordinal manner, higher-task to lower-task missions. By establishing such a hierarchy, an argument can be made to suggest that there may be a

point where two-seat operations should be maintained at least in some instances. Additionally, leverage can be generated for retention of the NFO in instances where an increase in crew workload is perceived to exist resulting from added technology in traditional two-seat missions.

Careful cause-and-effect relationships were hypothesized before conducting statistical tests in an effort to avoid "data mining" for results that may in fact not be there (Horngren, 1991:787). Ideally, the hypothesis should be generated before data collection and not reengineered in an effort to "make" the data fit.

Finally, a substantial effort was made to review all of the opinions contained in the comments section at the end of the survey to facilitate a qualitative analysis. Often, respondents demonstrated the need to explain or clarify answers beyond the scope of the instrument. This section was helpful in that it provided valuable insights and a guide for future study.

Summary

This chapter explained the basic plan of attack for solving a part of the overall crew complement issue facing the United States Armed Forces and specifically the United States Navy. A mail survey was used to measure attitudes of Navy pilots and NFOs towards the role of the NFO in current and future aircraft. In addition, the instrument measured the perceived effect of technology on aircrew workload across six specific mission types for future technology. Approximately one-sixth of all Navy aircrews currently assigned to fighter/attack roles from the

four main communities: F-14, F-18, A-6, and EA-6 responded. These responses were compiled and compared using statistical data analysis techniques and subjective assessments.

IV. Analysis

Introduction

This chapter describes the statistical and raw quantitative analysis of USN aircrew respondent data gathered via survey. The analysis is made to detect, measure, and illustrate variance and lack of variance across demographic and construct boundaries. Graphics are used to visually present the data by category. The analysis itself is divided into three major sections. Prior to these three sections, a description of individual variables analyzed and a demographic overview of the respondents themselves are presented. Additionally, a description of how to interpret the graphs is presented before analysis of data. The description of variables section includes an explanation of acronyms and a review of pertinent operational definitions. The demographic overview provides the background and experience level of individual respondents. The overview also provides a table highlighting representation by aircraft type and crew position.

As mentioned, the actual analysis of data gathered is presented in three sections. The structure of these three sections parallels the organization of the survey instrument itself. A current capabilities section provides aircrew perceptions in the context of capabilities existing in the respective aircraft flown. This current capabilities section is divided into mission areas. Each of the six mission areas addressed in the survey is analyzed. Only aircrew flying aircraft with a self-described capability in a respective mission area are included in

each mission category. The determination of this "self-described (mission) capability" is addressed in detail in the relevant section.

Next, data is gathered and analyzed in the context of the latest technology available (future section). The first part of the future section is divided in a similar fashion to the current capability analysis. It examines data from aircrew flying aircraft with a capability in a particular mission. An overall perception, generated by aircrew from all four aircraft, is also presented in each mission area. The remainder of the section is a demographic analysis using both two sample and paired t tests to once again detect, measure, and quantify variance or the lack of variance. Categorical analysis by rank, crew position, and combat experience is made.

The third major section analyzed is aircrew attitudes regarding technology and its impact on workload. This technology/workload comparison is made in the context of latest technology available. A thorough description of the specific context and variables measured in each of the three sections is provided in each of the individual sections.

Description of variables

The survey was specifically designed to measure a difference in operational effectiveness for combat aircraft in a one- and two-seat configuration. The independent variables used for this analysis are specific mission flown, aircraft currently flown, crew configuration (one or two), and technology. All four independent variables affect the

two mission-effectiveness dependent variables. Specifically, the mission effectiveness variables are mission success and survivability. Mission success is defined as the ability to literally complete the assigned mission. Survivability is defined as the ability to take off from station, operate in a hostile environment, and return to station. The independent variables, technology and mission flown, are directly tied to the dependent variable aircrew workload. Twenty-four variables measured each of the two mission effective variables for a total of 48 variables. Six variables specifically compared technology to workload. Each of the total 54 variables was measured directly by a specific question on the survey. The remainder of this section provides a description of the method used to code variables for ease of interpretation.

A simple three-letter acronym was used to label these six specific variables. The denotes technology. The second and third letters indicate the particular mission area in which the response was made. The six mission areas and their abbreviations are listed below:

AS	Air Superiority
CA	Close Air Support
LT	Low/Medium Threat Interdiction
HT	High Threat Interdiction
NT	Night/All-Weather Interdiction
SD	Suppression of Enemy Air Defenses.

It is acknowledged that standard abbreviations exist for some of these missions. In an effort to minimize the number of characters used in naming variables, the standard abbreviations were limited to only two characters. Normally, software programs limit variable names to eight characters or less. Creating two-character names for specific missions

allowed for compliance with this requirement. For example, the variable used to measure technology's affect on workload for the Air Superiority mission would is TAS.

The remaining 48 (non-technology) variables actually represent a series of the same four core questions measured in both a current and future context (24 each). The series of four questions is asked in each of the six mission areas. The four questions ask aircrew for a perception of one- and two-seat performance in the two mission effectiveness categories (success and survivability). These 48 variables all contain seven-letter acronyms as labels. The first letter denotes whether the variable is measured in a current or future context (section I or section II of the survey). "C" indicates current and "F" indicates future. The second letter denotes single- or two-seat, "S" or "T." The third, fourth, and fifth letter denotes which dependent variable is being measured, "SUC" for success or "SUR" for survivability. The last two letters indicate which mission area is measured using the same six mission abbreviations used in the technology section above. For example, "CTSUCAS" is a variable measuring a response for current, two seat, mission success in the air superiority mission. The acronym FSSURNT is a variable measuring the response for future, one seat, survivability in the night/all weather interdiction mission.

Demographics

In chapter three the population size was presented in Table 1. As mentioned, of 960 surveys distributed, 290 responses were received, for an overall response rate of 30%. Of the 290 responses, 153 were from pilots and 137 were from NFOs. This response rate is lower than expected, but sufficient for statistical analysis. The response rates by type aircraft and specific rating (pilot or NFO) are provided in Table 2.

While the response rates in some communities may seem low, a number of reasons can explain this phenomenon in part. The numbers used to calculate the number of surveys sent to each unit were based on full unit manning. It is likely that some units were not fully manned. Negative responses due to personal leave and temporary assigned duty requirements are also acknowledged as a possibility for nonresponse.

TABLE 2

AIRCREW SURVEY RESPONSE RATES

CATEGORY		SENT	RESPONSES	RATE %
F/A-18	pilot	192	53	28
A-6	pilot	96	38	40
A-6	NFO	96	31	32
EA-6	pilot	36	19	53
EA-6	NFO	108	59	55
F-14	pilot	192	43	22
F-14	NFO	192	44	23

The responses by rank included two O-6s (airwing commanders), 18 O-5s (squadron commanders and executive officers), 60 O-4s, 183 O-3s, 25 O-2s, and one O-1. Of the 290 respondents, 138 had combat experience, 62 pilots and 71 NFOs. Additionally, 175 of the 290 had been an FRS instructor or a squadron NATOPS evaluator.

As stated in Chapter 3, one aim of this research was to solicit responses from experienced aircrew members. In this regard the low response rates are not particularly disturbing. The sample had a high percentage of combat-experienced aircrew and aircrew with significant flight experience. A significant number of senior and experienced aircrew did take the time to respond.

Rank and flight time were found to closely parallel each other in analysis. An O-3 with significant flight experience responded much the same as an O-4 with the same level of flight experience. This lack of variance between rank and flight time allowed categorical analysis by one category instead of two. For ease of interpretation the rank category was selected.

Graph interpretation

Before presenting the analysis of data, this section will provide a description of the graphical technique used. The majority of the graphs in this chapter will portray a shaded area representing a confidence interval. For consistency, a 90% confidence level is used throughout the research. The mean of the respective confidence interval is annotated with a horizontal line. The span of a particular

confidence interval is a measure of the variance of that particular variable. The 90% confidence interval is especially meaningful. It indicates that there is a 90% probability that the true sample mean of the population in question falls within the interval shown. Using these confidence intervals one can visually inspect for statistical significance by checking for overlap of the intervals of interest. For example, if an A-6 one-seat confidence interval overlaps the A-6 two-seat confidence interval for the same mission effectiveness category, the difference is not statistically significant.

Each graph is identified at the top by aircraft flown. The scale on the ordinate axis displays the degree to which the respondents agree that survivability and success are enhanced in the one-seat and two-seat configurations. The letters SA, A, N, DA, and SD represent strongly agree, agree, neutral, disagree, and strongly disagree respectively.

Current

This section was designed to measure the perceptions of aircrew in the context of existing technology in the aircraft they currently fly. As previously mentioned, a series of four core questions measured success and survivability for both a one- and two-seat configuration of the aircraft. The four core questions were asked in each mission area. A hypothetical crew complement change for a respective aircraft was designed to allow direct measure of the aircrews level of confidence for both one- and two-seat configurations. Potential confounds associated with this hypothetical crew complement change were minimized by careful

wording in the survey instructions (ref Appendix B). The above structure results in twenty-four specific variables measuring each respondent's perceptions in this current context. The 24 specific variables are listed in Table 3.

TABLE 3

LIST OF VARIABLES MEASURED IN CURRENT SECTION

VARIABLE	EXPLANATION OF VARIABLE NAME
CSSURAS	Current single-seat survivability air superiority
CSSUCAS	Current single-seat success air superiority
CTSURAS	Current two-seat survivability air superiority
CTSUCAS	Current two-seat success air superiority
CSSURCA	Current single-seat survivability CAS
CSSUCCA	Current single-seat success CAS
CTSURCA	Current two-seat survivability CAS
CTSUCCA	Current two-seat success CAS
CSSURLT	Current single-seat survivability lo/med tht interdiction
CSSUCLT	Current single-seat success lo/med tht interdiction
CTSURLT	Current two-seat survivability lo/med tht interdiction
CTSUCLT	Current two-seat success lo/med tht interdiction
CSSURHT	Current single-seat survivability high tht interdiction
CSSUCHT	Current single-seat success high tht interdiction
CTSURHT	Current two-seat survivability high tht interdiction
CTSUCHT	Current two-seat success high tht interdiction
CSSURNT	Current single-seat survivability night interdiction
CSSUCNT	Current single-seat success night interdiction
CTSURNT	Current two-seat survivability night interdiction
CTSUCNT	Current two-seat success night interdiction
CSSURSD	Current single-seat survivability SEAD
CSSUCSD	Current single-seat success SEAD
CTSURSD	Current two-seat survivability SEAD
CTSUCSD	Current two-seat success SEAD

The bulk of this section is a series of graphs displaying a categorical analysis of attitudes regarding one- and two-seat capability. This analysis is made for all aircraft with at least a secondary capability in each of the six particular mission areas.

Though aircraft categories are important, the analysis is further divided by crew position.

The amount of capability for each of the four aircraft in a respective mission area was determined by the aircrew themselves. Using the survey instrument, aircrew members were asked to provide their primary mission area. In a follow-on question, they were asked to indicate any secondary missions their aircraft was capable of performing. By using a quantitative analysis by frequency of response, each aircraft was rated as having primary, secondary, or no capability, for each of the six missions listed. By allowing respondents to make up their own minds about a mission, no relevant inputs were excluded. If a significant portion of a certain aircraft population indicated a secondary capability in a particular mission, that mission was included. More than one primary mission was allowed to accommodate multi-role aircraft. The determination of mission capability is important for the analysis contained in Chapter Four and Five. Table 4 summarizes the results of this analysis.

This methodology facilitates a visual comparison of aircrew flying aircraft with a shared mission. Differing individual capabilities of aircraft in respective mission areas make comparisons inexact. Age of individual aircraft design and priority placed on various missions potentially cause a significant variance in capability for different aircraft in a shared mission area. It was considered useful, however, to provide these comparisons. For example, it is interesting to measure how F-14 pilots believed survivability and success were affected by

TABLE 4

MATCHING AIRCRAFT TO PRIMARY, SECONDARY, AND MISSIONS NOT PERFORMED

AIRCRAFT	MISSION AREA					
	AS	CA	LT	HT	NT	SEA
F/A-18	PRI	PRI	PRI	PRI	SEC	SEC
F-14	PRI	SEC	SEC	NC	NC	NC
A-6	NC	PRI	SEC	SEC	PRI	SEC
EA-6B	NC	NC	NC	NC	NC	PRI

variations in crew size compared to how F/A-18 pilots rated the same variables in any particular mission. The most useful result of the current aircraft data and analysis is the perception of how crew size impacts a specific aircraft's mission effectiveness in each of the six missions.

Air Superiority

In the air superiority mission only two of the four aircraft reported a capability. The F-14 and the F/A-18 both reported air superiority as a primary mission area. The F/A-18 aircrew indicated they were both more survivable and successful in a one-seat configuration at the 90% confidence level. F-14 pilots and NFOs indicated that they were both more survivable and successful in a two-seat configuration. F-14 NFOs demonstrated the largest variance between one- and two-seat responses for both success and survivability. The mean NFO response in a one-seat configuration for both success and

survivability indicated slight disagreement. Given a one-seat version of the F-14, the radar intercept officers (RIO) disagreed that the aircraft would be either survivable or successful. Reference Figures 1,2, and 3.

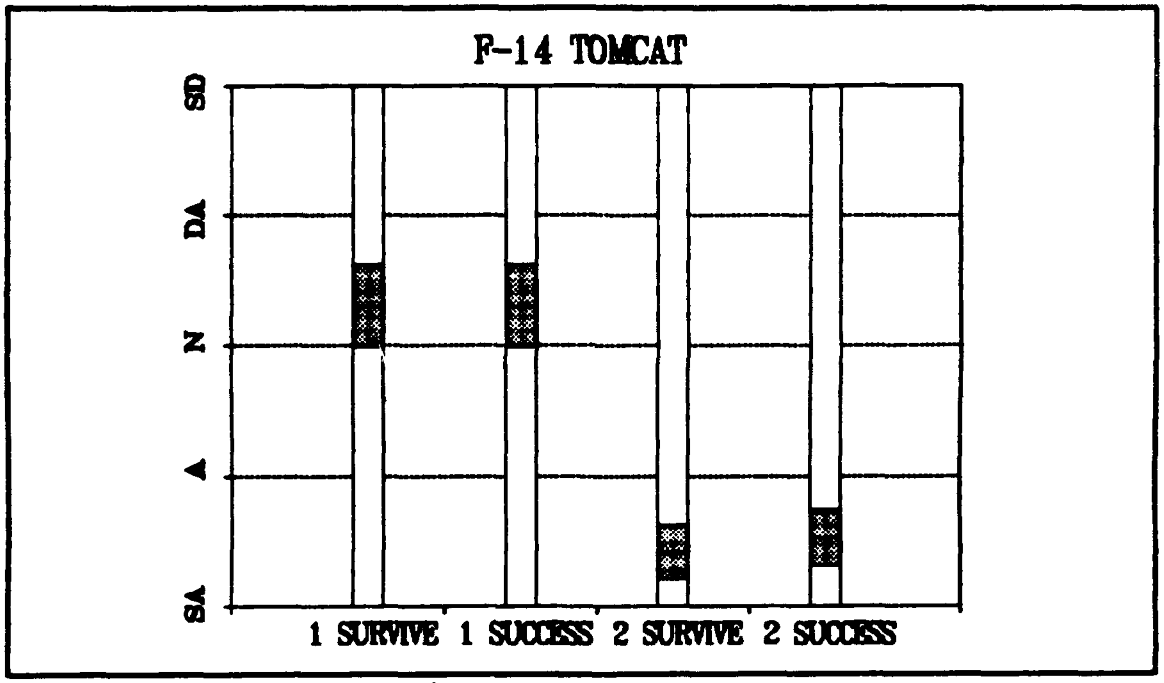

Figure 1. F-14 NFOs' Response to Air Superiority Questions

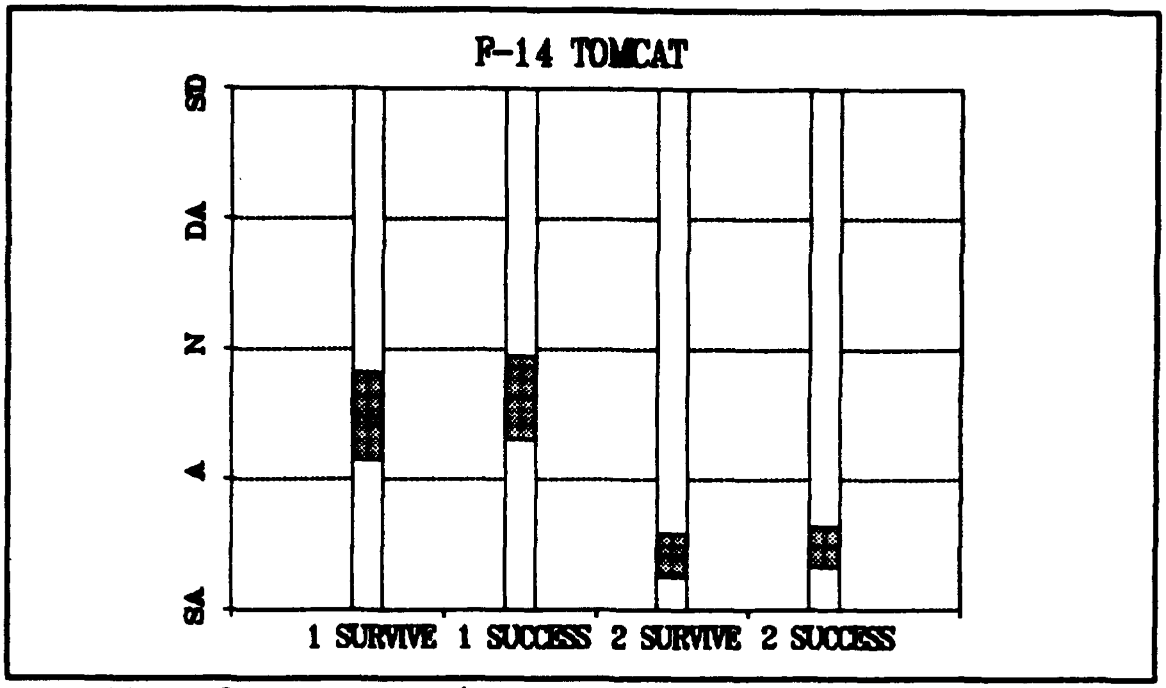

Figure 2. F-14 Pilots' Response to Air Superiority Questions

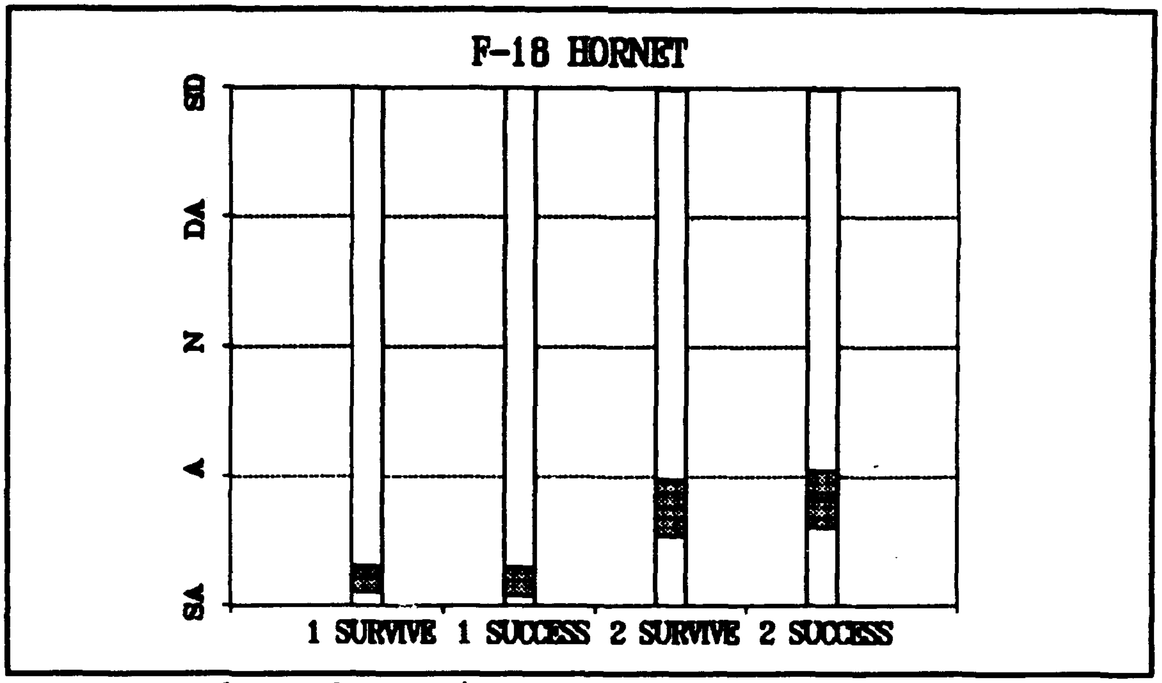

Figure 3. F-18 Pilots' Response to Air Superiority Questions

Close Air Support

The next mission analyzed is close air support (CA). F/A-18 and A-6 aircrew listed this as a primary mission, while F-14 aircrew rated it a secondary mission. F/A-18 pilots indicated that they were slightly more survivable in a one-seat configuration. While the F/A-18 mean response for one-seat was better than two-seat for mission success, the responses did not statistically vary at the 90% confidence level. F/A-18 pilots indicated the CA mission was executable in either configuration. F-14 pilots indicated they were significantly more survivable and successful in a two-seat configuration. They were in fact neutral regarding their capability single seat from both a survivability and success perspective. F-14 NFOs were less confident overall than pilots in both the one- and two-seat configurations. Both F-14 pilot and NFO responses were statistically significant and in favor of a two-seat configuration. Both fell in the slightly disagree range for survivability and success single-seat. F-14 aircrew slightly agreed that for the two-seat configuration they would be both survivable and successful. Relative to F-14 pilots, F-14 NFOs were less optimistic in this mission area. A-6 pilots rated two-seat success and survivability significantly better than one. They indicated slight disagreement with having a capability across both mission effectiveness categories in a one-seat configuration. A-6 NFOs were extremely confident of success and survivability in a two-seat configuration. They indicated slight to strong disagreement in both effectiveness categories in a one-seat configuration. Figures 4 through 8 illustrate these findings.

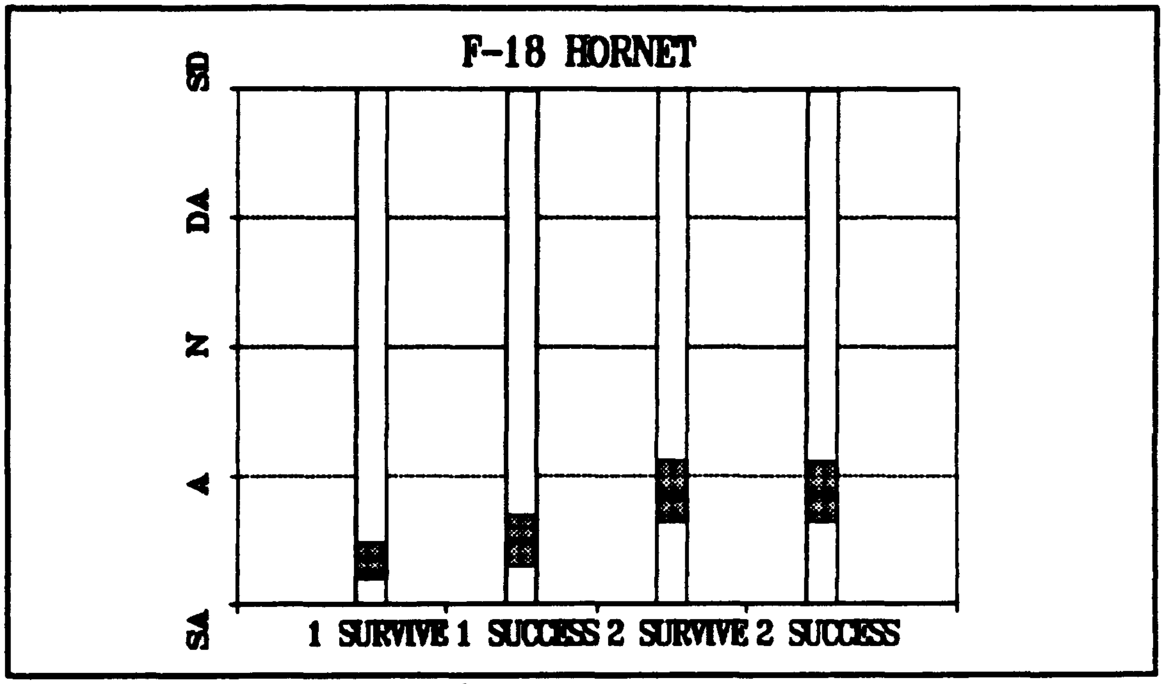

Figure 4. F-18 Pilots' Response to Close Air Support Questions

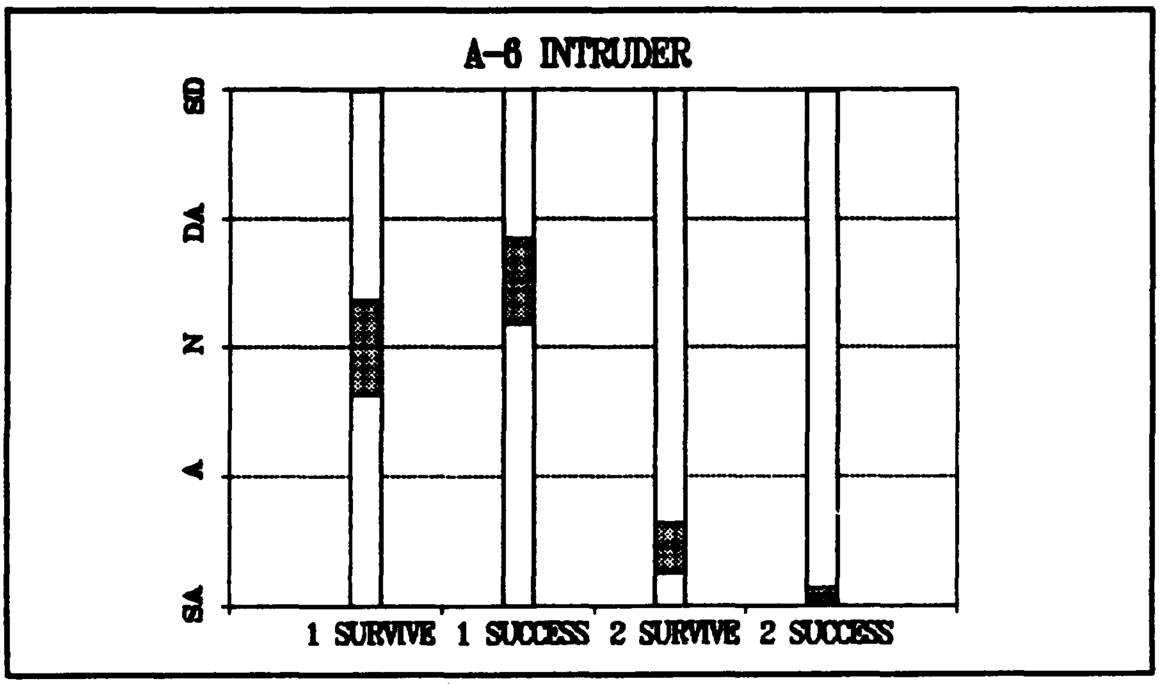

Figure 5. A-6 Pilots' Response to Close Air Support Questions

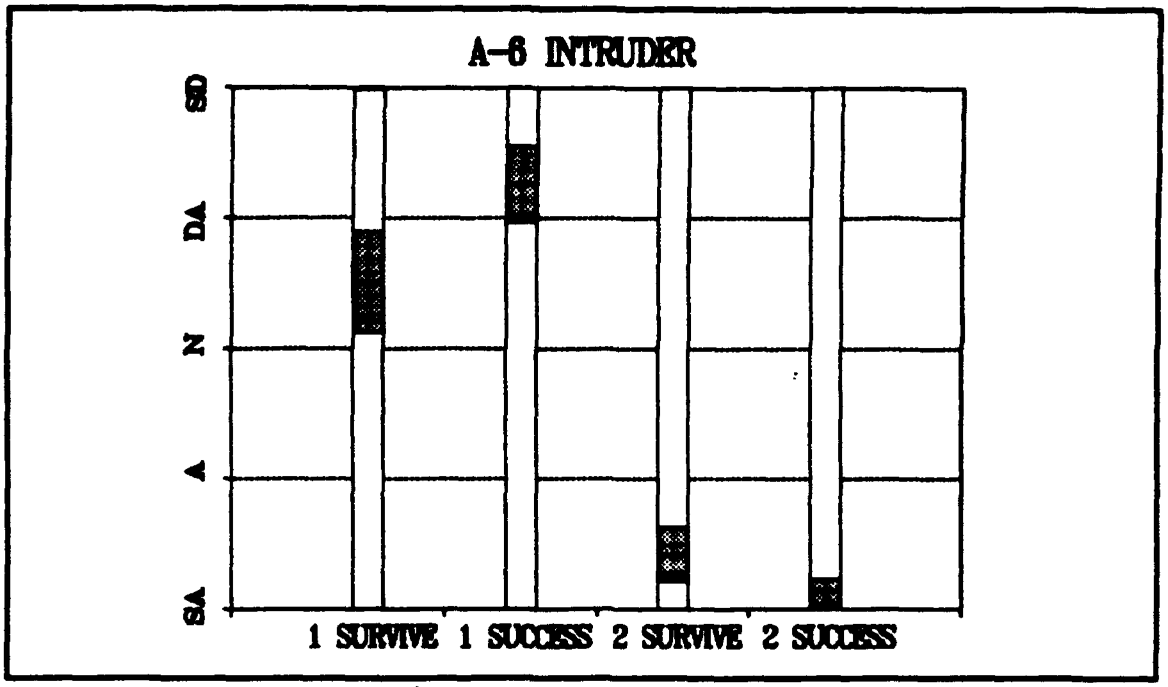

Figure 6. A-6 NFOs' Response to Close Air Support Questions

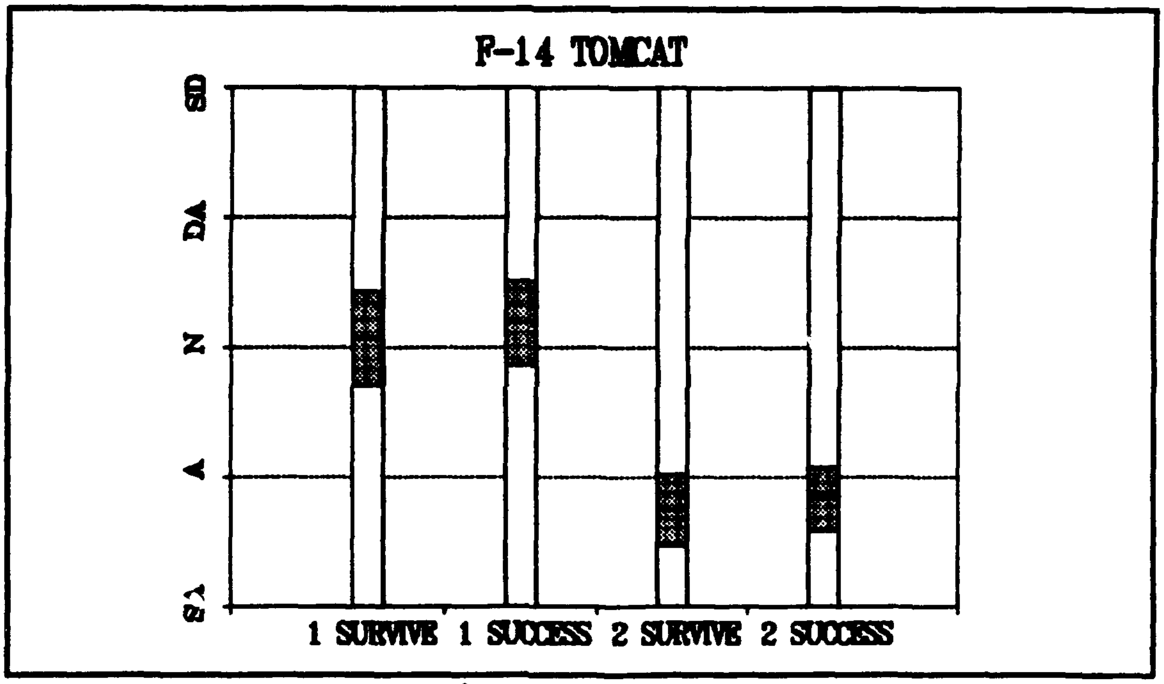

Figure 7. F-14 Pilots' Response to Close Air Support Questions

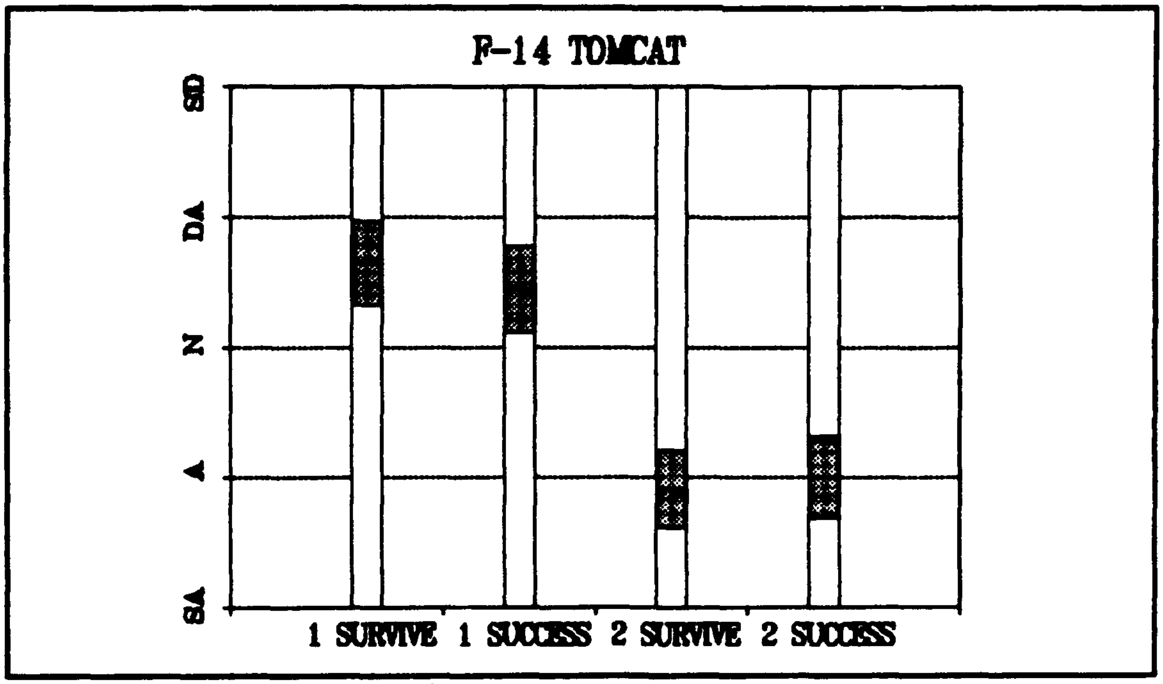

Figure 8. F-14 NFOs' Response to Close Air Support Questions

Low/Medium Threat Interdiction

In the low threat mission area three of the four aircraft had at least a secondary capability. The F-14, the A-6 and the F/A-18 results are analyzed. The results closely parallel the analysis made in the close air support mission. The F/A-18 pilots once again believed they were more capable in a one-seat configuration. They did agree they would be both successful and survivable in a two-seat configuration, but to a lesser degree than in one. The difference between one- and two-seat perceptions for the F/A-18 is statistically significant at the 90% confidence level. F-14 and A-6 pilots and NFOs indicated they would be more effective in a two-seat configuration for both success and survivability. The difference between one- and two-seat perceptions is statistically significant at the 90% confidence interval for all four

groups. F-14 NFOs, and A-6 pilots and NFOs were neutral regarding success and survivability in a one-seat configuration. F-14 pilots were more optimistic about both mission effectiveness factors in the one-seat configuration. Reference Figures 9 through 13 for illustration.

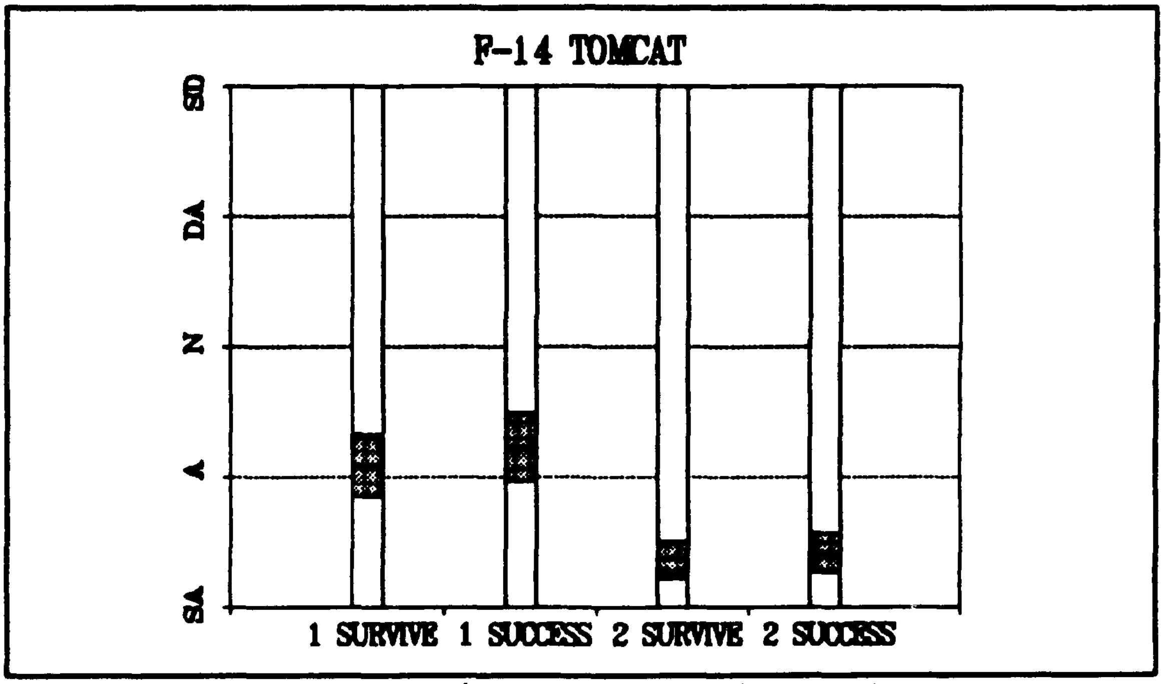

Figure 9. F-14 Pilots' Response to Low/Medium Threat Interdiction Questions

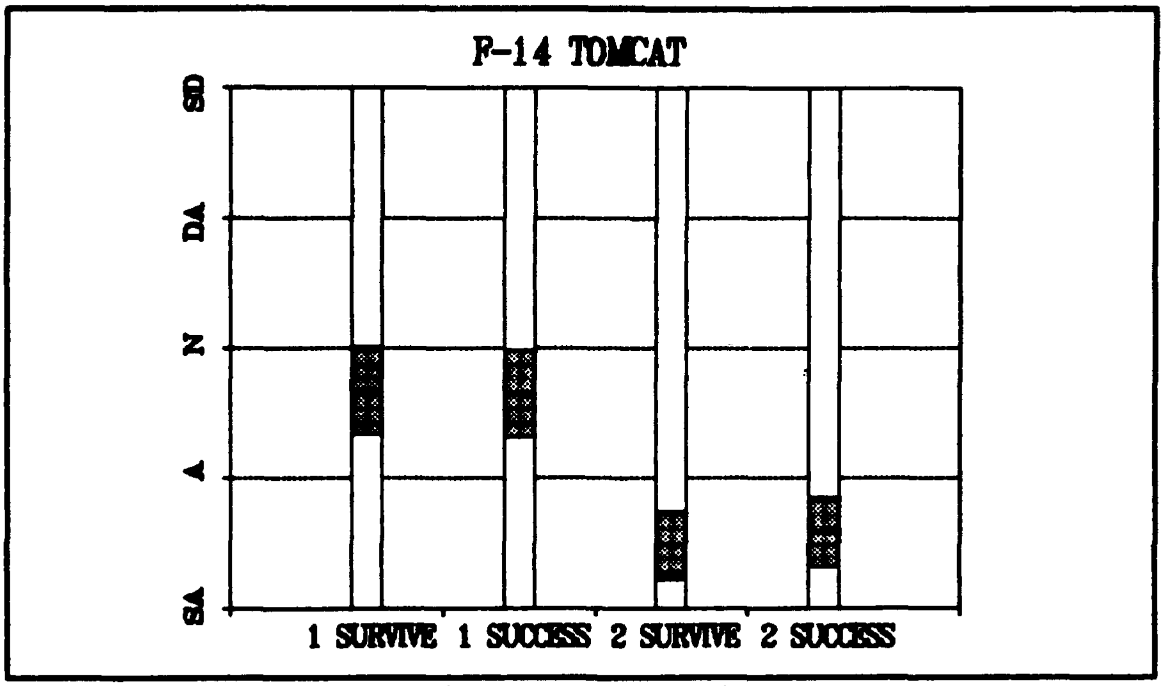

Figure 10. F-14 NFOs' Response to Low/Medium Threat Interdiction Questions

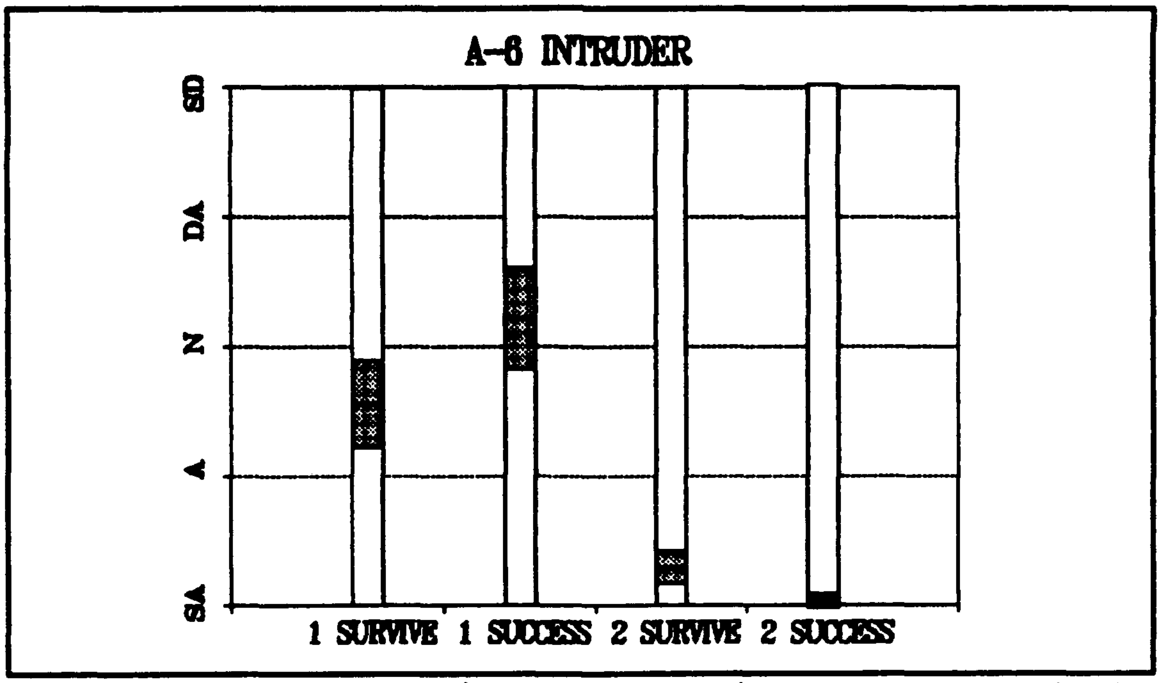

Figure 11. A-6 Pilots' Response to Low/Medium Threat Interdiction Questions

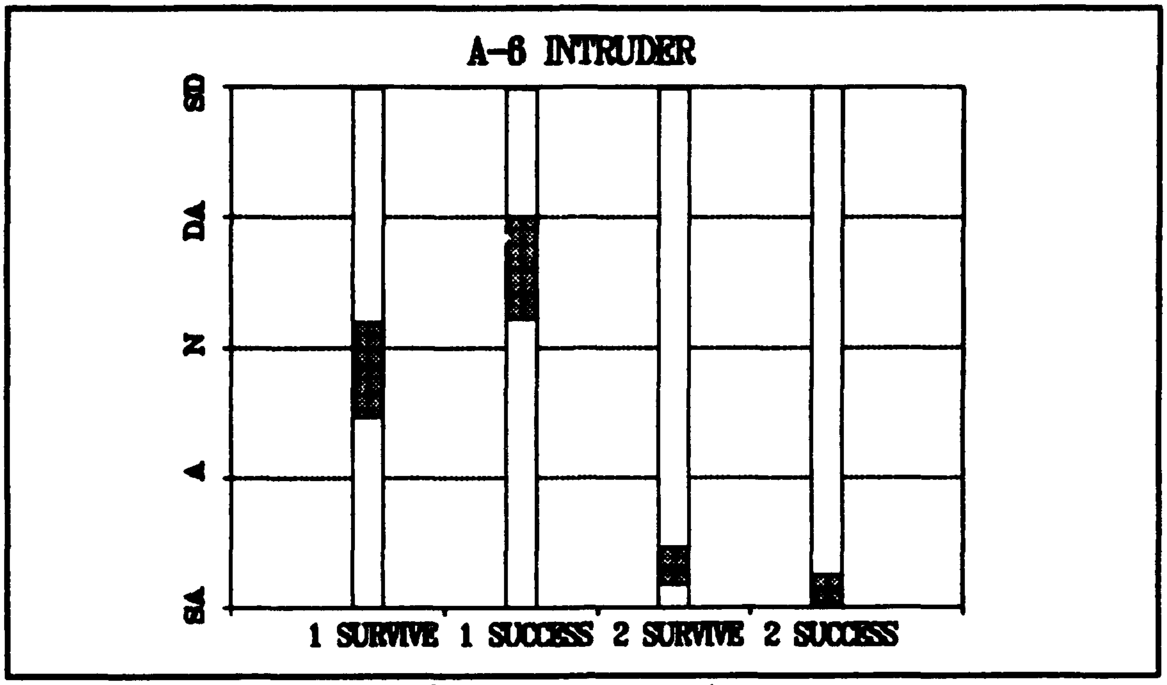

Figure 12. A-6 NFOs' Response to Low/Medium Threat Interdiction Questions

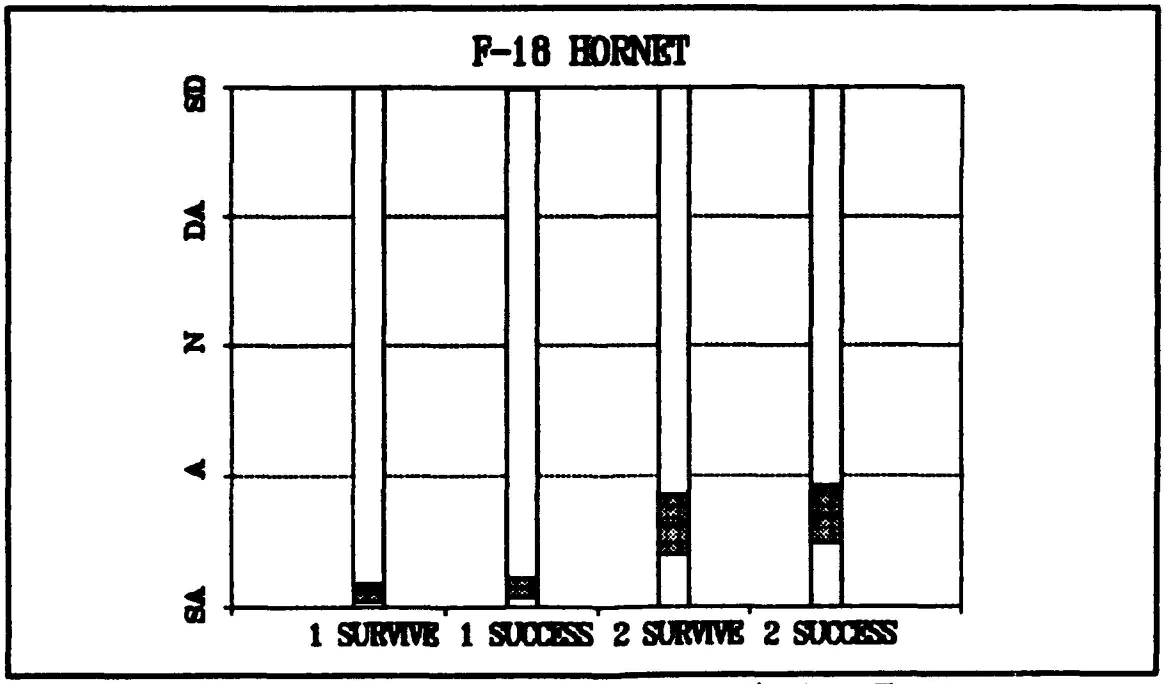

Figure 13. F-18 Pilots' Response to Low/Medium Threat Interdiction Questions

High Threat Interdiction

In the area of high threat interdiction (HT) the A-6 and F/A-18 aircrew members were analyzed. F/A-18 pilots were reasonably confident in both the one- and two-seat configurations. While the mean responses for the one-seat configuration are slightly more optimistic, at the 90% level of confidence no preference can be ascertained. In both configurations F/A-18 pilots indicated slightly more confidence in mission success than in survivability. A-6 pilots indicated approximately the same level of confidence in the two-seat configuration of their aircraft as the F/A-18 pilots had in a one-seat configuration. They were not confident in a one-seat configuration for either success or survivability. A-6 pilots demonstrated a preference for a two-seat configuration at the 90% level of confidence. In a one-seat configuration the A-6 pilots indicated more confidence in survivability than in success. In the two-seat configuration the A-6 pilots reversed this trend and indicated more confidence in success than survivability. A-6 pilots rate the contribution from NFOs more important for mission success than for survivability. A-6 NFO results closely parallel those of A-6 pilots. They also indicate that the addition of a crewmember contributed more to success than to survivability. Figures 4-14 through 4-16 illustrate these findings.

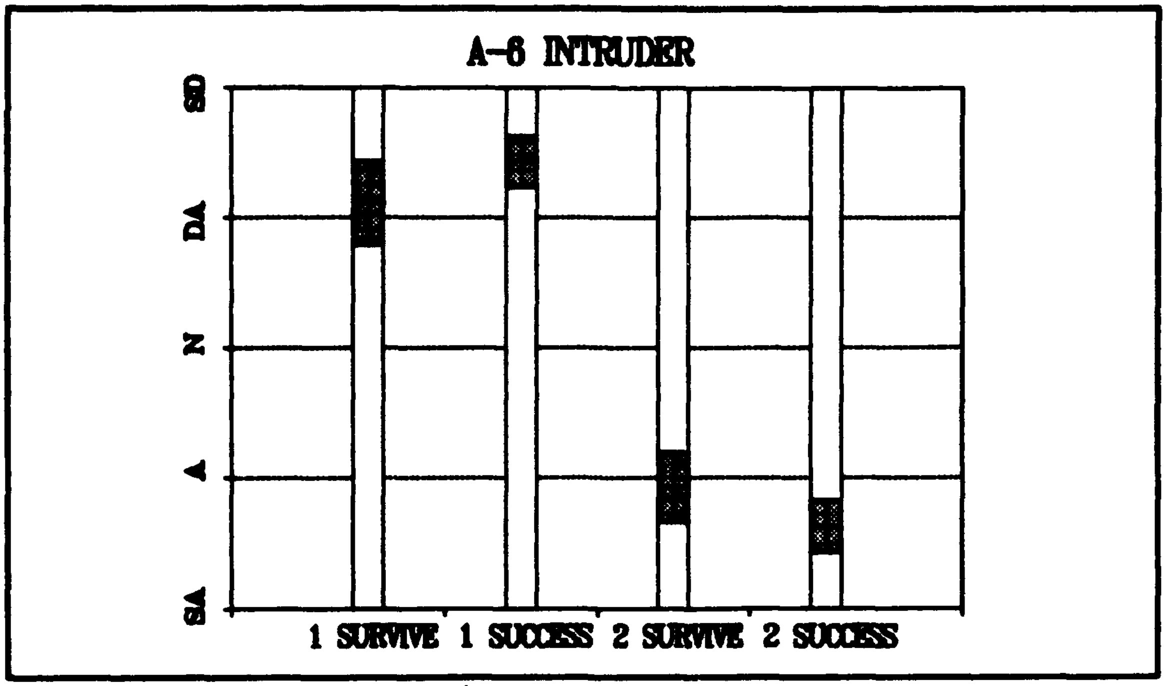

Figure 14. A-6 Pilots' Response to High Threat Interdiction Questions

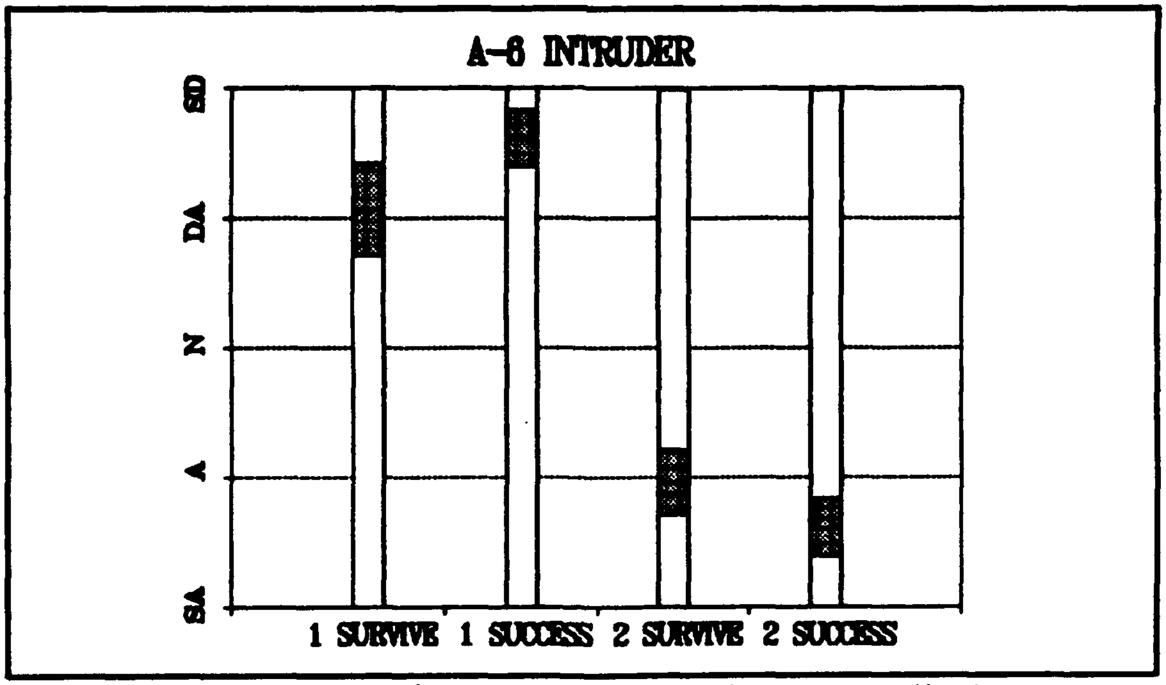

Figure 15. A-6 NFOs' Response to High Threat Interdiction Questions

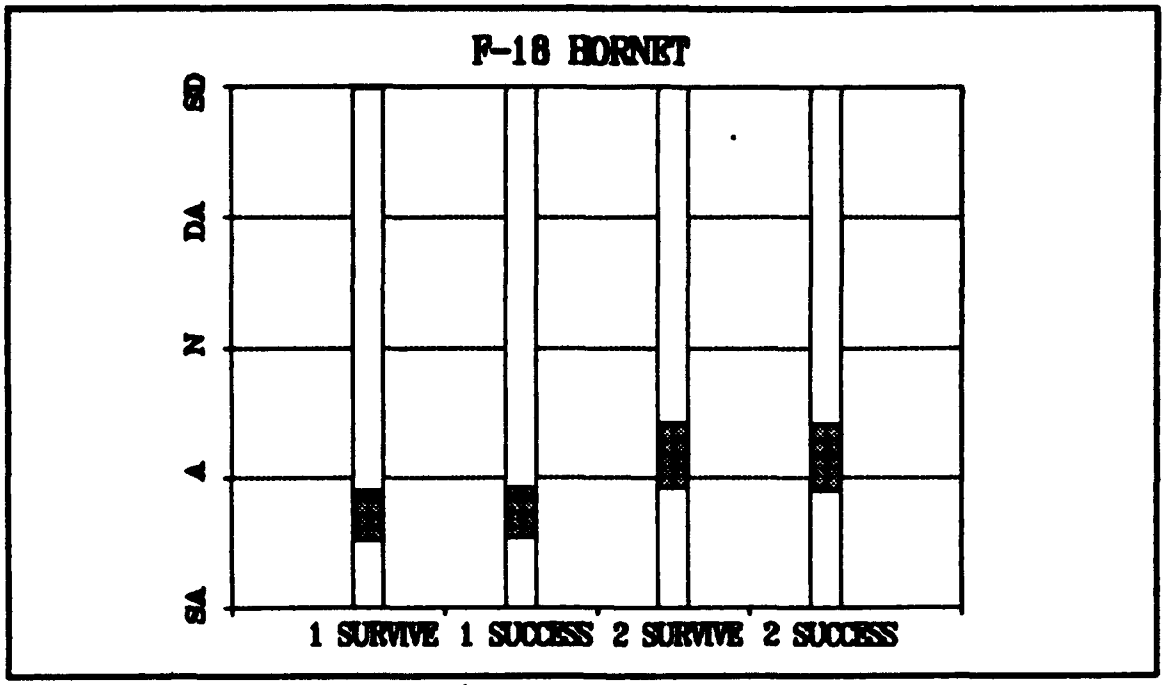

Figure 16. F-18 Pilots' Response to High Threat Interdiction Questions

Night/All-Weather Interdiction

The A-6 and F/A-18 were considered to have a mission capability in the night/all weather interdiction mission (NT). F/A-18 pilots did not indicate a statistical preference for one- or two-seat configurations in either survivability or success at the 90% level of confidence. The mean response in each of the four categories shows that F/A-18 pilots see themselves as slightly more survivable in a one-seat configuration, but slightly more successful in a two-seat configuration. The night interdiction mission is the only mission where the F/A-18 pilot's mean response was more favorable for a two-seat configuration. As mentioned, these preferences were slight, and not statistically significant. A-6 pilots indicated a high degree of confidence for both success and

survivability in a two-seat configuration. They were significantly less confident in a one-seat configuration. As in high threat, they indicated the addition of a crewmember to be more important from a success standpoint than that of survivability. A-6 NFOs were even more confident than A-6 pilots of success and survivability in a two-seat configuration. They were more pessimistic in both effectiveness categories in a one-seat configuration. They, like their pilot counterparts, believed the presence of an additional crewmember contributed relatively more to success than to survivability. A-6 pilots and NFOs demonstrated a preference for a two-seat configuration in the NT mission at the 90% confidence level. Figures 17 through 19 illustrate the findings for the NT mission.

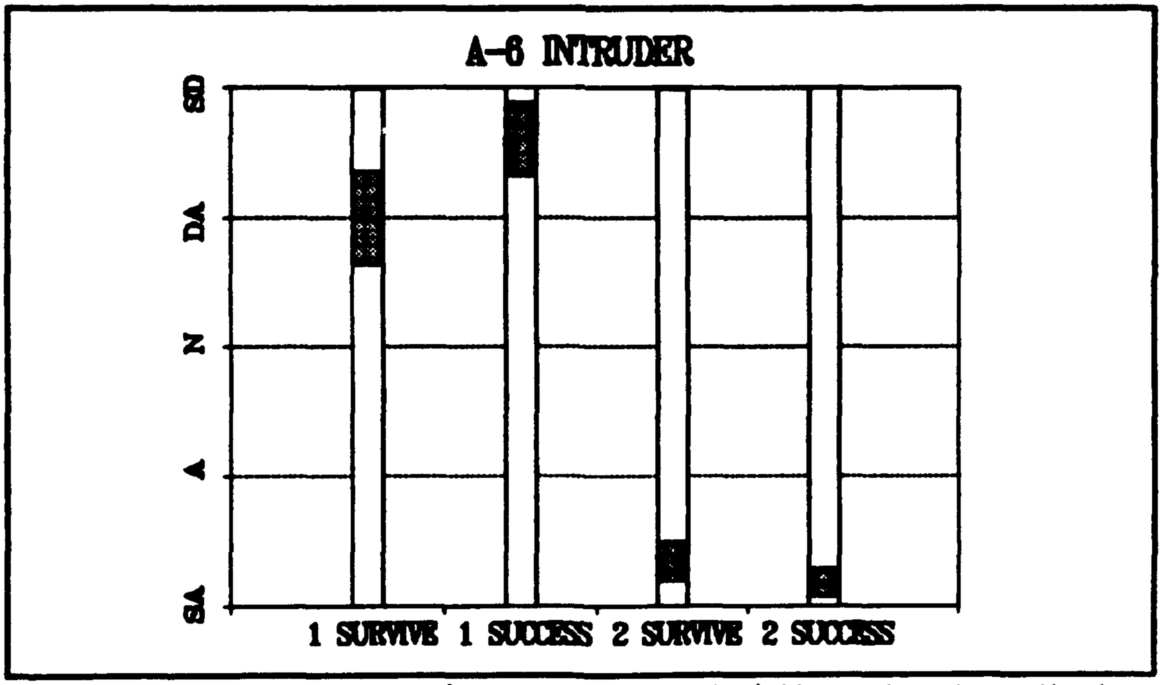

Figure 17. A-6 Pilots' Response to Night/All-Weather Interdiction Questions

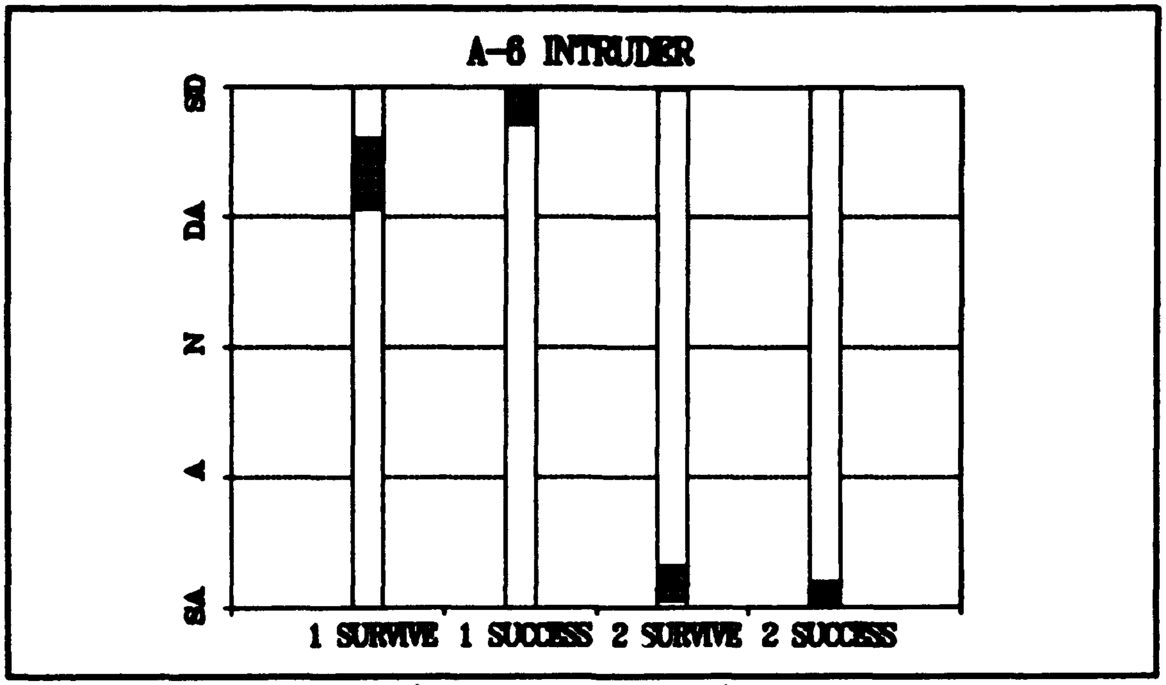

Figure 18. A-6 NFOs' Response to Night/All-Weather Interdiction Questions

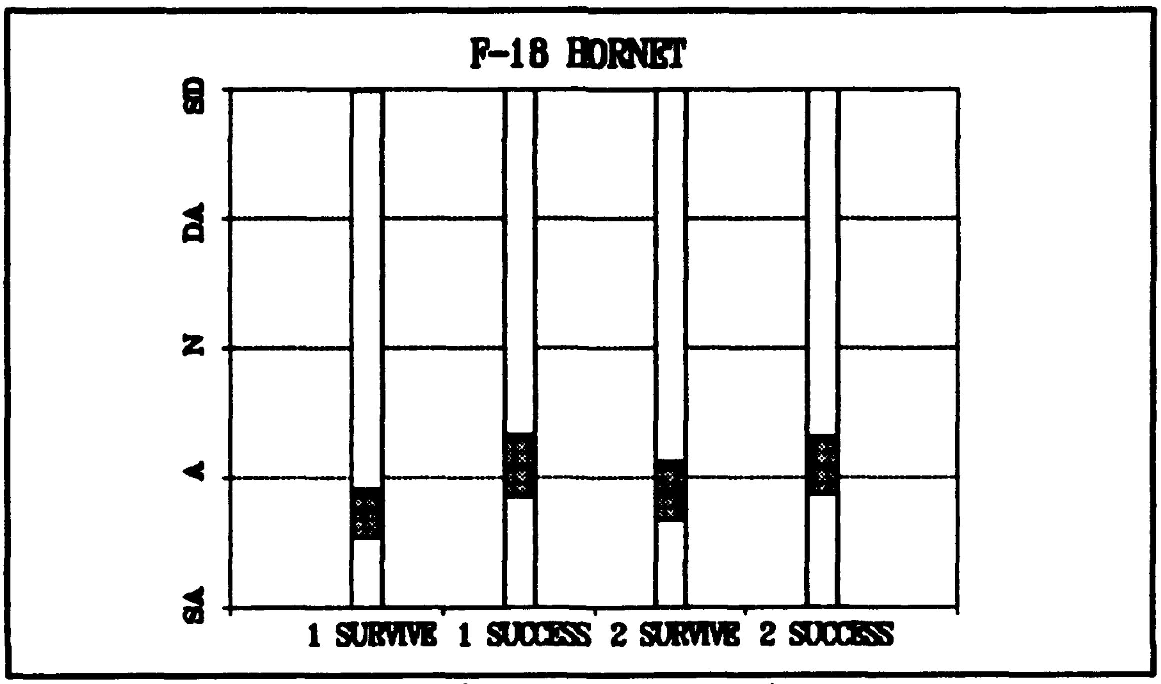

Figure 19. F-18 Pilots' Response to Night/All-Weather Interdiction Questions

Suppression of Enemy Air Defenses

Three of the four aircraft have at least a secondary capability in suppression of enemy air defenses (SD). The aircraft included in the analysis are the EA-6. the A-6, and the F/A-18. F/A-18 pilots were highly confident of success and survivability in this mission in a one-seat configuration. They were also confident in both effectiveness categories for a two-seat configuration but less so for one-seat. The F/A-18 difference in preference for both effectiveness categories was statistically significant at the 90% level of confidence. F/A-18 pilots indicated that survivability was of less concern in both one- and two-seat configurations. A-6 pilots and NFOs were both confident of success and survivability in a two-seat configuration. A-6 pilots were fairly confident of survivability in a one-seat configuration but less confident of mission success. A-6 NFOs were neutral regarding one-seat capability in either effectiveness category. EA-6 pilots were fairly confident of both survivability and success in a two-seat configuration. They were not confident of either success or survivability in a one-seat configuration. The difference between two-seat and one-seat survivability for the EA-6B pilots was statistically significant at a 90% level of confidence. EA-6B NFO results closely matched that of EA-6B pilots. They too significantly favored a two-seat configuration. EA-6 NFOs believe the addition of a crewmember contributed more to mission success than to survivability. Figures 20 through 24 illustrate the findings in the SD mission.

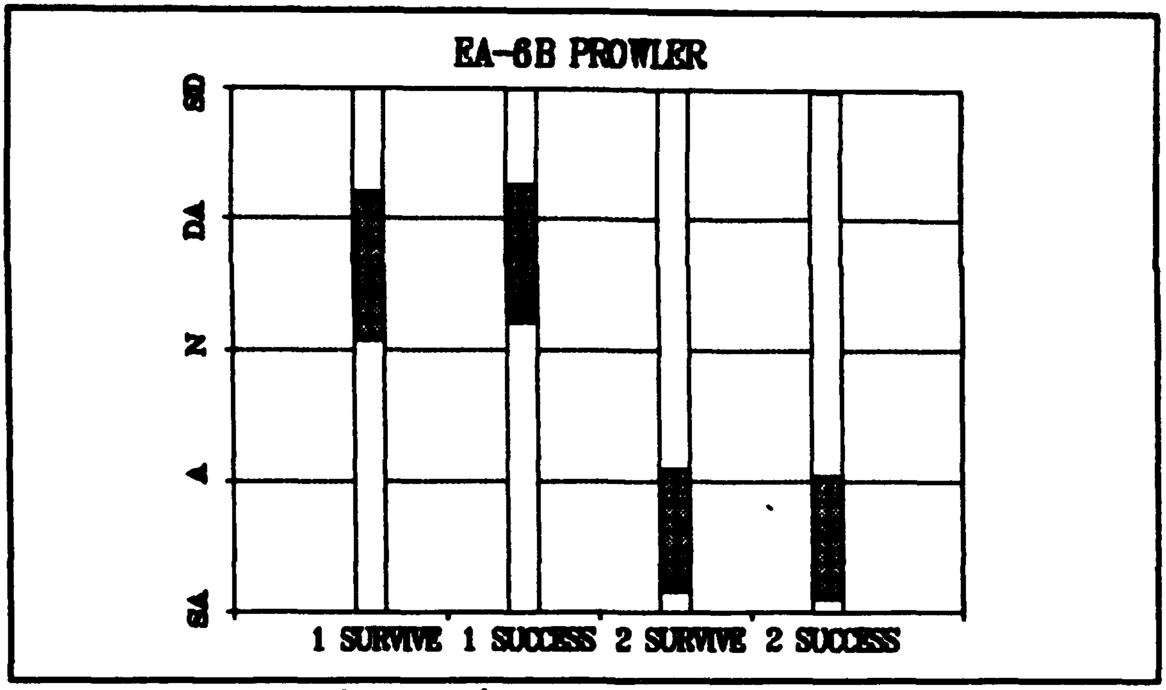

Figure 20. EA-6B Pilots' Response to Suppression of Enemy Air Defenses Questions

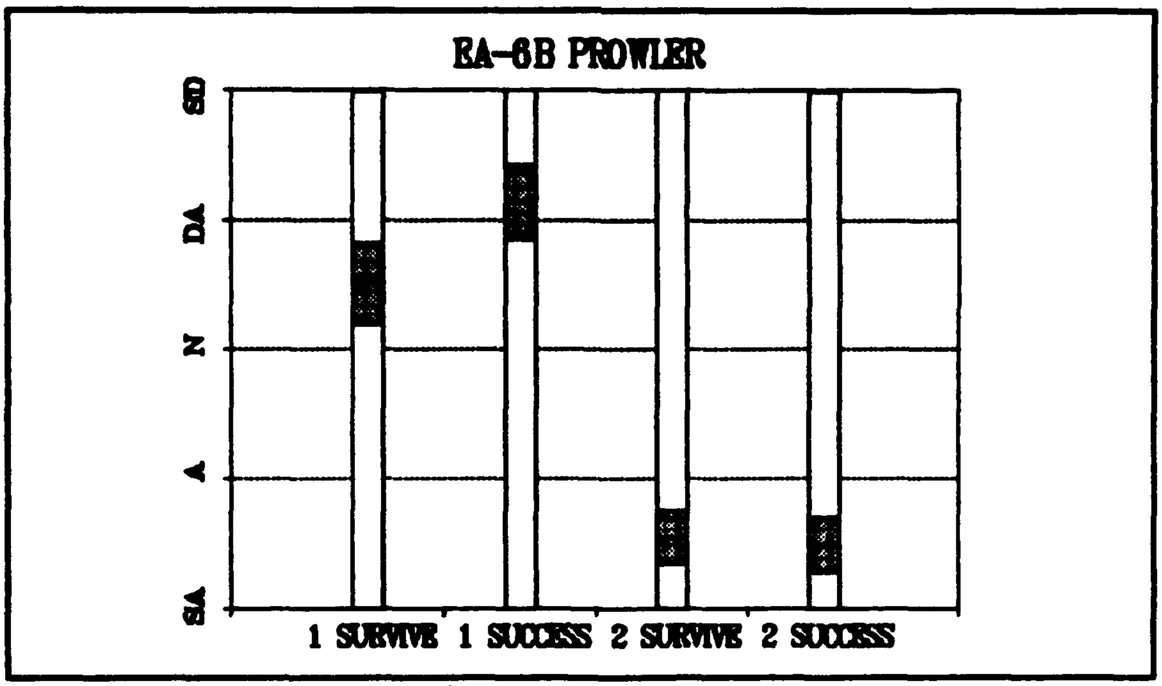

Figure 21. EA-6B NFOs' Response to Suppression of Enemy Air Defenses Questions

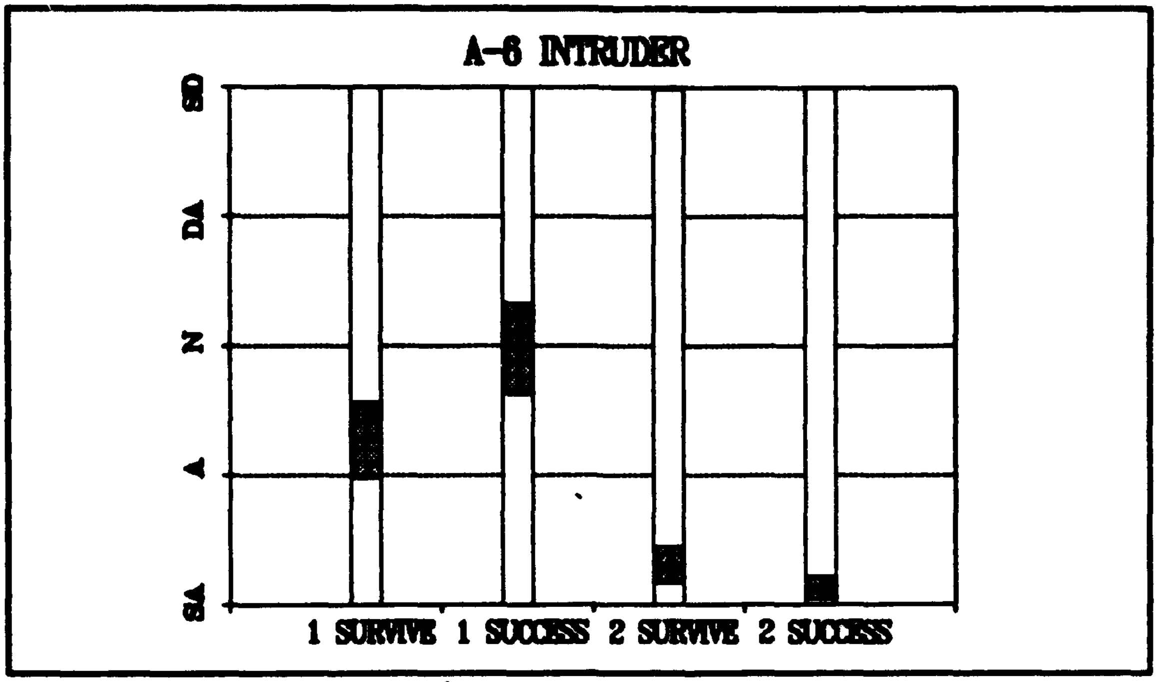

Figure 22. A-6 Pilots' Response to Suppression of Enemy Air Defenses Questions

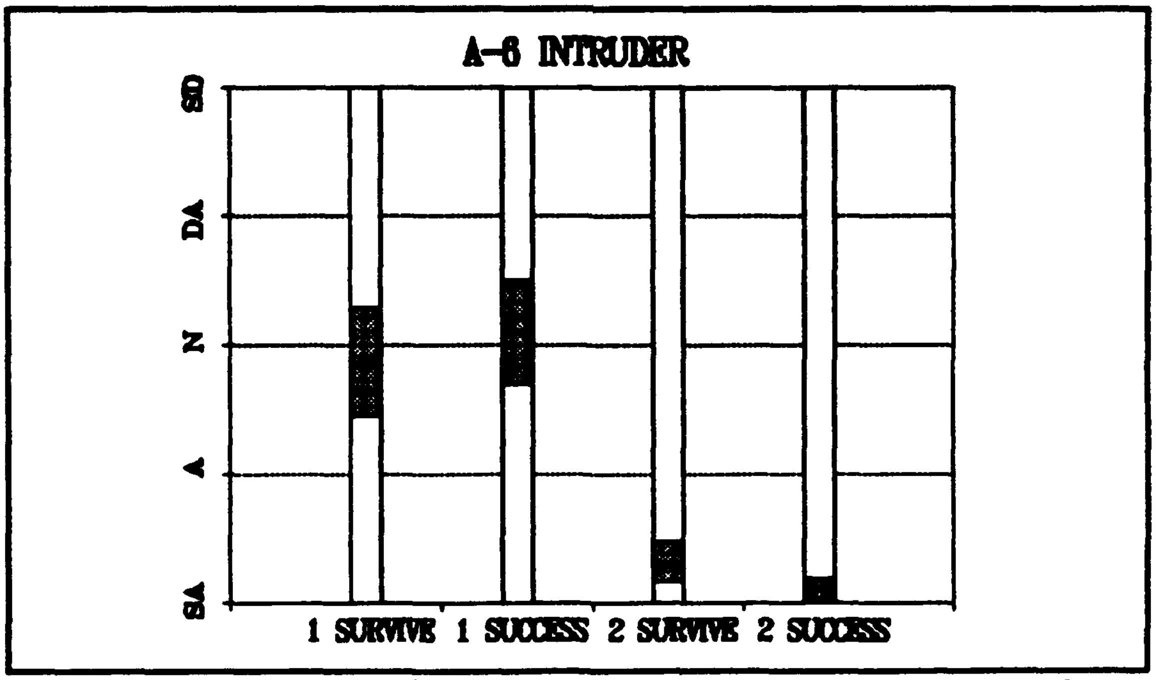

Figure 23. A-6 NFOs' Response to Suppression of Enemy Air Defenses Questions

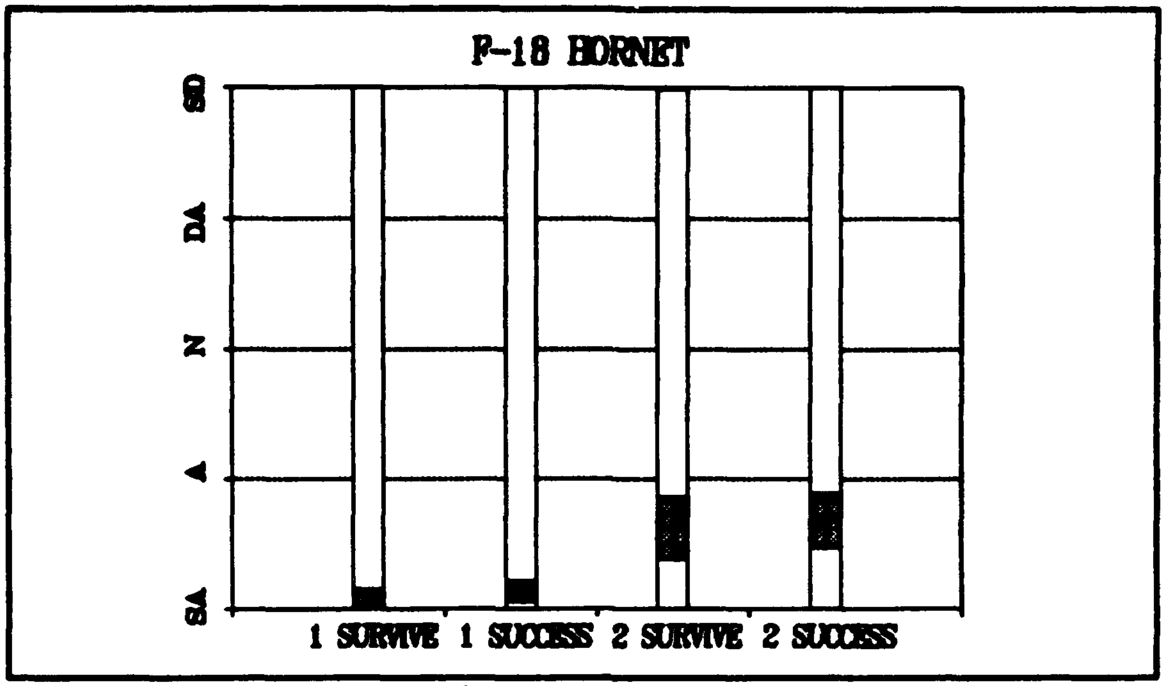

Figure 24. F-18 Pilots' Response to Suppression of Enemy Air Defenses Questions

Future

This section will present data about perceived future combat capabilities. It is organized similar to the section on current operations, but expanded to include an overall view in each mission area. In this overall analysis, responses from all aircrew flying all four aircraft types are included. This overall analysis is presented prior to looking at aircrew flying aircraft with a mission capability in a particular mission area. Following overall and aircraft category analyses, the data will be divided along demographic lines to include comparisons between pilots and NFOs, aircrew with and without combat time, and opinions by respondents of different rank.

The future analysis is conducted in the context of the next generation fighter. As in the first section, 24 variables are used to measure responses across six mission areas. Aircrew respond given what they perceive will be optimal technology to perform each respective mission. The particular capabilities of the aircraft they currently fly only serve as a building block to estimate what future technology will be. The same mission effectiveness variables, success and survivability, are used. The 24 specific variables are listed in Table 5.

TABLE 5

LIST OF VARIABLES MEASURED IN FUTURE SECTION

VARIABLE	EXPLANATION OF VARIABLE NAME
FSSURAS	Future single-seat survivability air superiority
FSSUCAS	Future single-seat success air superiority
FTSURAS	Future two-seat survivability air superiority
FTSUCAS	Future two-seat success air superiority
FSSURCA	Future single-seat survivability CAS
FSSUCCA	Future single-seat success CAS
FTSURCA	Future two-seat survivability CAS
FTSUCCA	Future two-seat success CAS
FSSURLT	Future single-seat survivability lo/med tht interdiction
FSSUCLT	Future single-seat success lo/med tht interdiction
FTSURLT	Future two-seat survivability lo/med tht interdiction
FTSUCLT	Future two-seat success lo/med tht interdiction
FSSURHT	Future single-seat survivability high tht interdiction
FSSUCHT	Future single-seat success high tht interdiction
FTSURHT	Future two-seat survivability high tht interdiction
FTSUCHT	Future two-seat success high tht interdiction
FSSURNT	Future single-seat survivability night interdiction
FSSUCNT	Future single-seat success night interdiction
FTSURNT	Future two-seat survivability night interdiction
FTSUCNT	Future two-seat success night interdiction
FSSURSD	Future single-seat survivability SEAD
FSSUCSD	Future single-seat success SEAD
FTSURSD	Future two-seat survivability SEAD
FTSUCSD	Future two-seat success SEAD

Air Superiority

For the air superiority mission, the analysis in the future context proved similar to that the current capabilities analysis. Overall, respondents indicated that future single-seat operations would enjoy moderate success and likely be survivable. They further rated survivability higher than they rated success. The contrast between single-seat and two-seat operations was pronounced. Two-seat operations were overwhelmingly preferred from both a survivability and a success standpoint. These differences were statistically significant.

While the overall data on air superiority displays the combined perspective for all four tactical aircraft, it is useful to look at responses from the communities who normally perform the mission. F/A-18 pilots differ significantly from the overall perspective. They are much more optimistic about one-seat success and survivability than other aircraft crewmembers. F/A-18 pilots rated both one- and two-seat performance as highly capable in both mission effectiveness categories. However, they statistically preferred one-seat operations over two-seat operations at the 90% level of confidence. F/A-18 pilots rated two-seat survivability slightly higher than two-seat success in this mission.

The one-seat ratings were nearly identical. F-14 pilots rated air superiority similarly to that seen in the overall analysis for this mission area. They did, however, give one-seat capabilities a higher rating than that of the main population. The F-14 pilots indicated a statistical preference for two-seat operations at the 90% confidence level. There were no significant differences or trends with respect to

survivability and success. F-14 NFOs, while acknowledging a limited single-seat capability, have great confidence in future two-seat operations. F-14 NFO results closely parallel the overall findings. Compared to F-14 pilots, NFOs rate single-seat capabilities slightly less effective than do pilots and two-seat capabilities slightly better. They are the most optimistic group regarding two-seat performance in the air superiority mission. Air superiority data is displayed graphically in Figures 25 through 28.

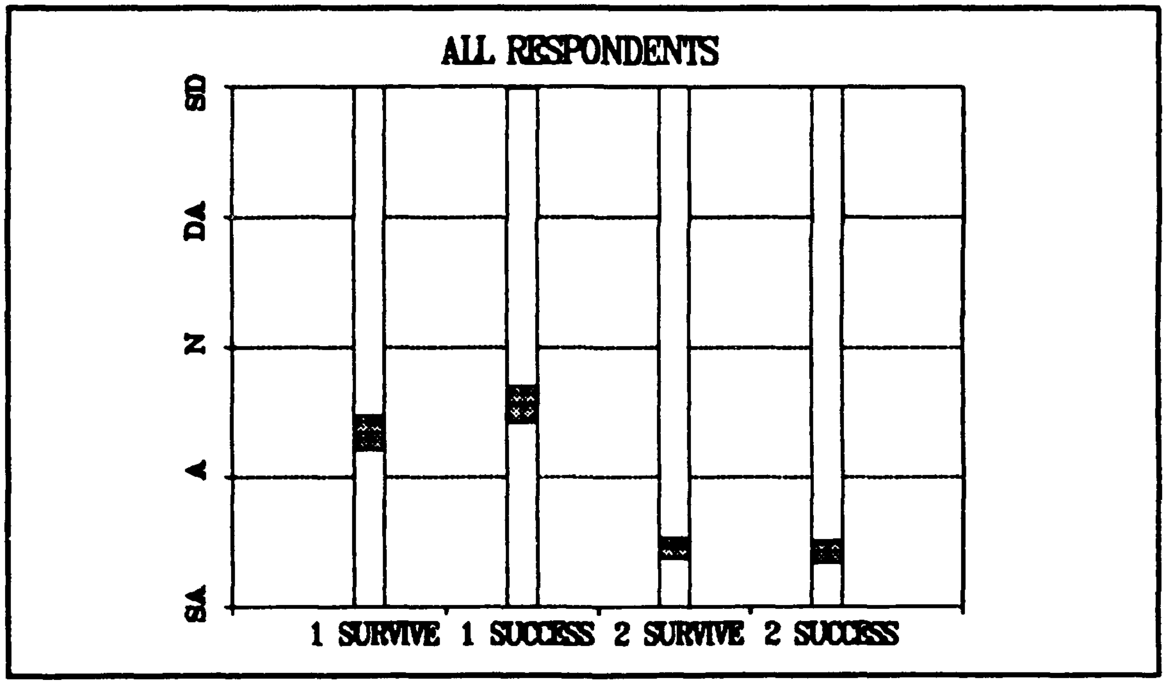

Figure 25. Combined Reply of All Respondents to Air Superiority Questions in a Future Context

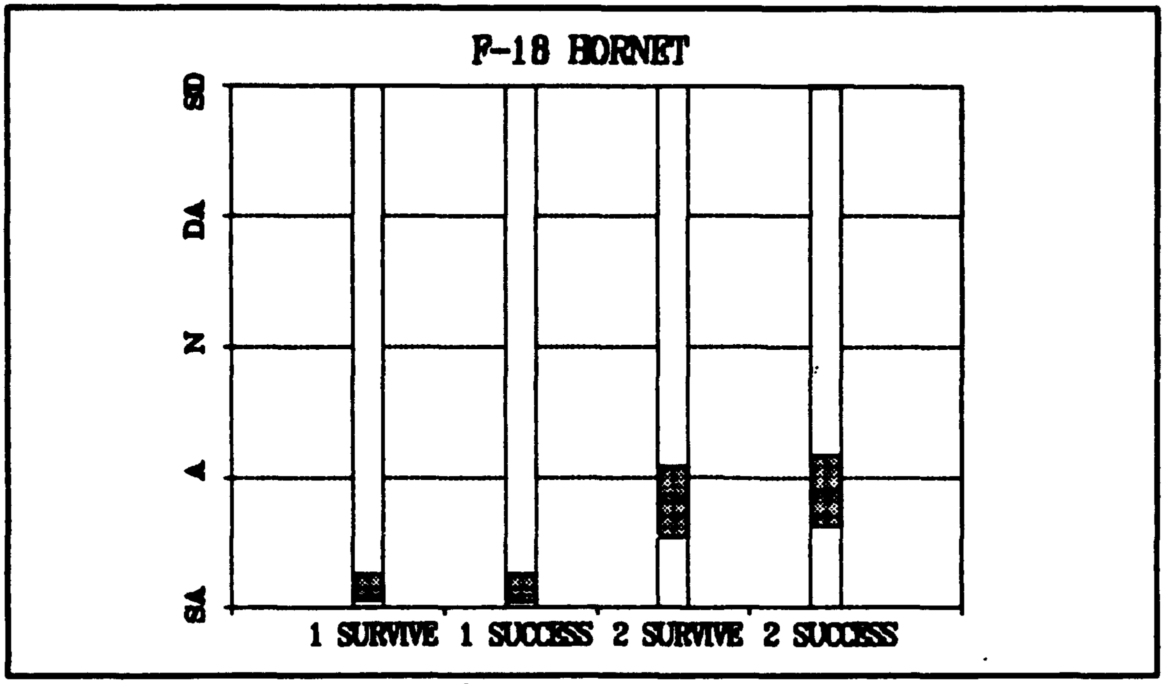

Figure 26. F-18 Pilots' Response to Air Superiority Questions in a Future Context

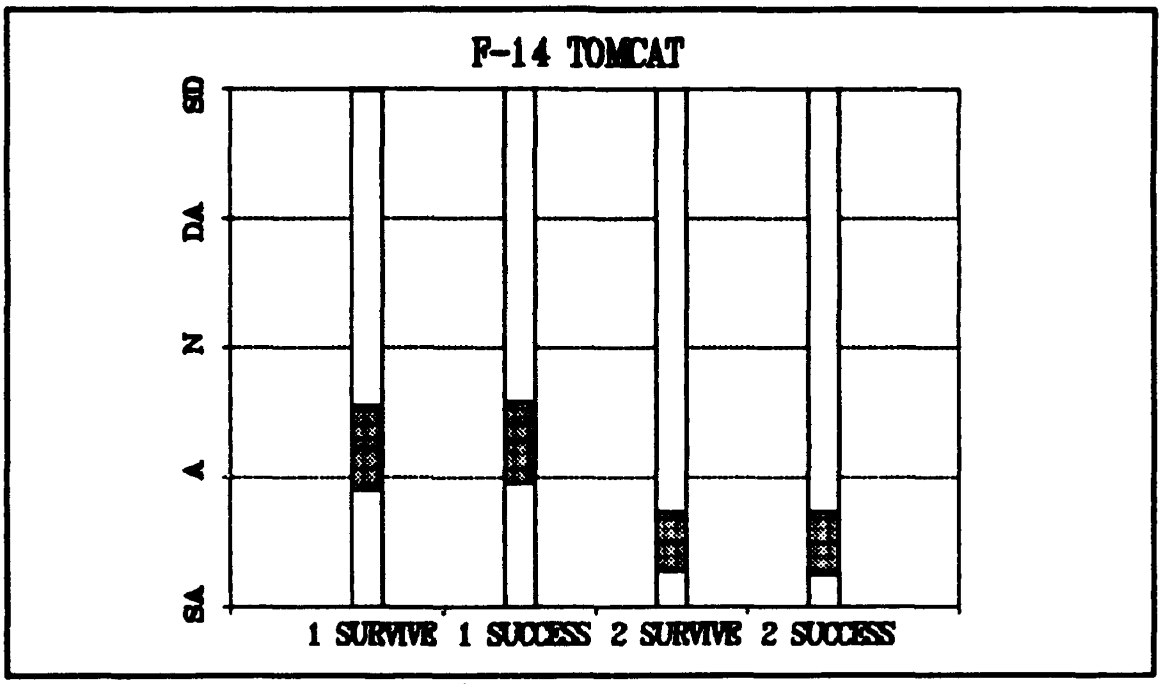

Figure 27. F-14 Pilots' Response to Air Superiority Questions in a Future Context

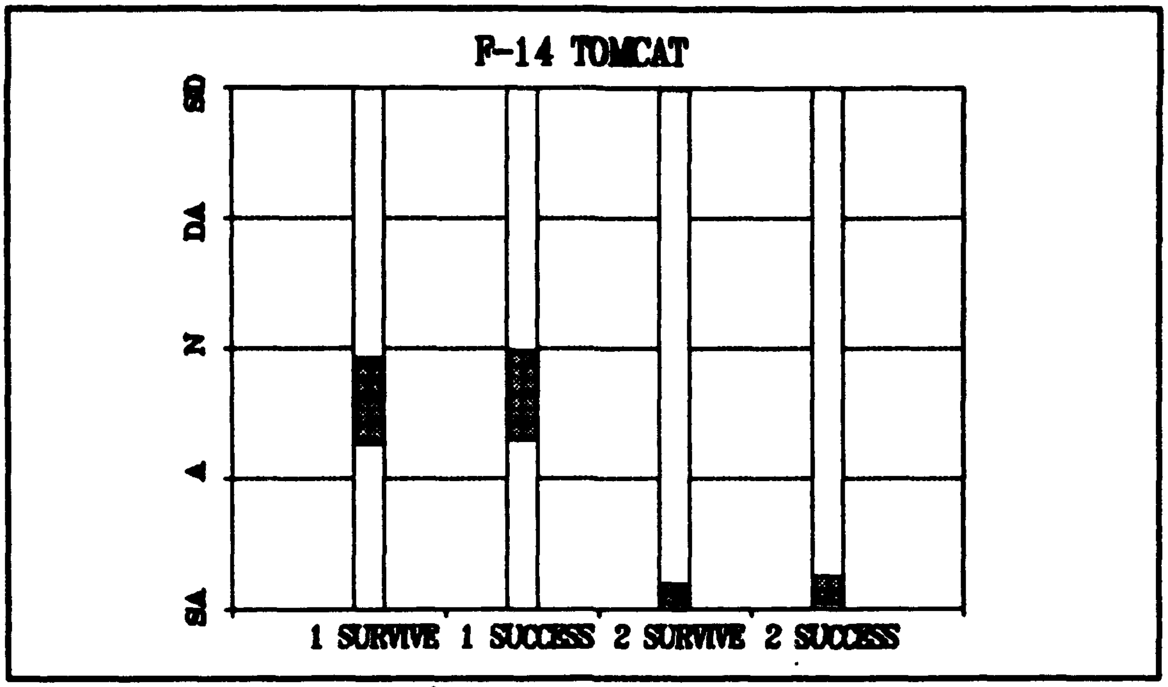

Figure 28. F-14 NFOs' Response to Air Superiority Questions in a Future Context

Close Air Support

The data on the CAS role is similar to that of the air superiority role. The A-6, F/A-18, and F-14 data will be analyzed here. A-6 pilots and NFOs both show weak support for single-seat operations in CAS and strong support for two-seat operations. Consistent with the last section, they rate success higher than survivability in the two-seat area and survivability higher than success in the single-seat area. The next two figures summarize this data.

Once again, F/A-18 responses support single-seat operations in the CAS role. They show strong confidence in the single-seat mission and slightly weaker but adequate support for two-seat operations. Though the F-14's primary mission is air superiority, the aircraft has been

used in the CAS role in the past and will continue to be used for CAS in the future. F-14 pilot and NFO responses agree with regard to two-seat operations, but once again, the pilots give single-seat operations slightly more capability than do the NFOs. The CAS data in whole favors two-seat operations on the one hand, but shows limited support for single-seat operations as well. Data concerning the CAS mission is contained in Figures 29 through 34.

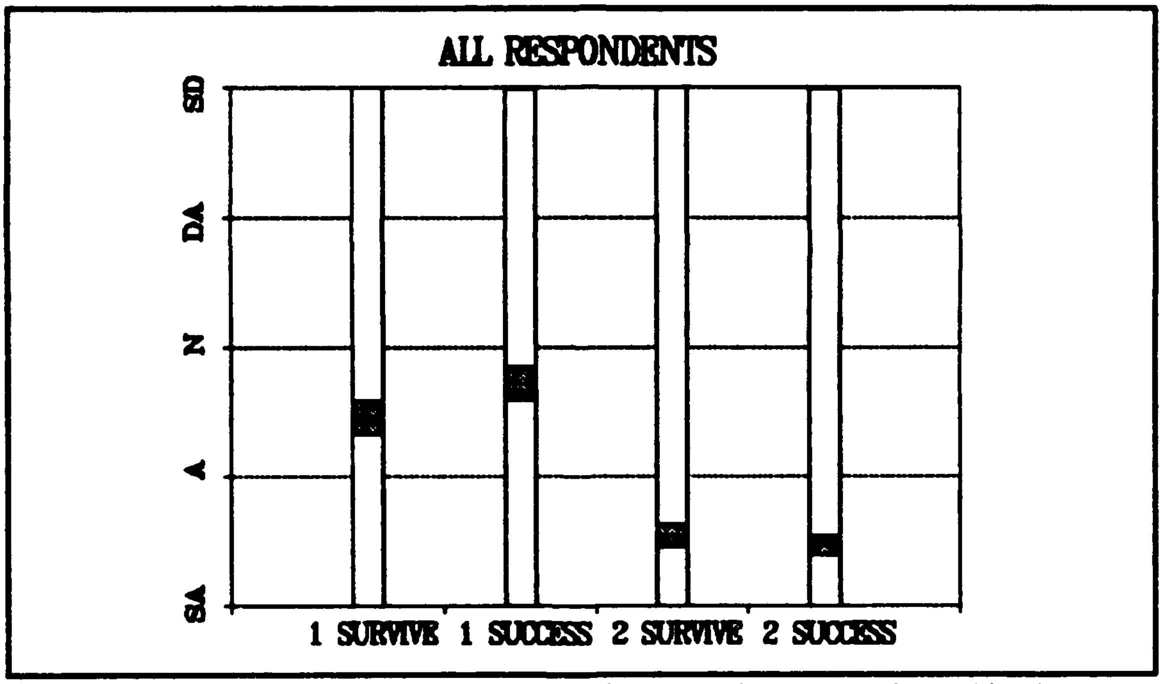

Figure 29. Combined Reply of All Respondents to Close Air Support Questions in a Future Context

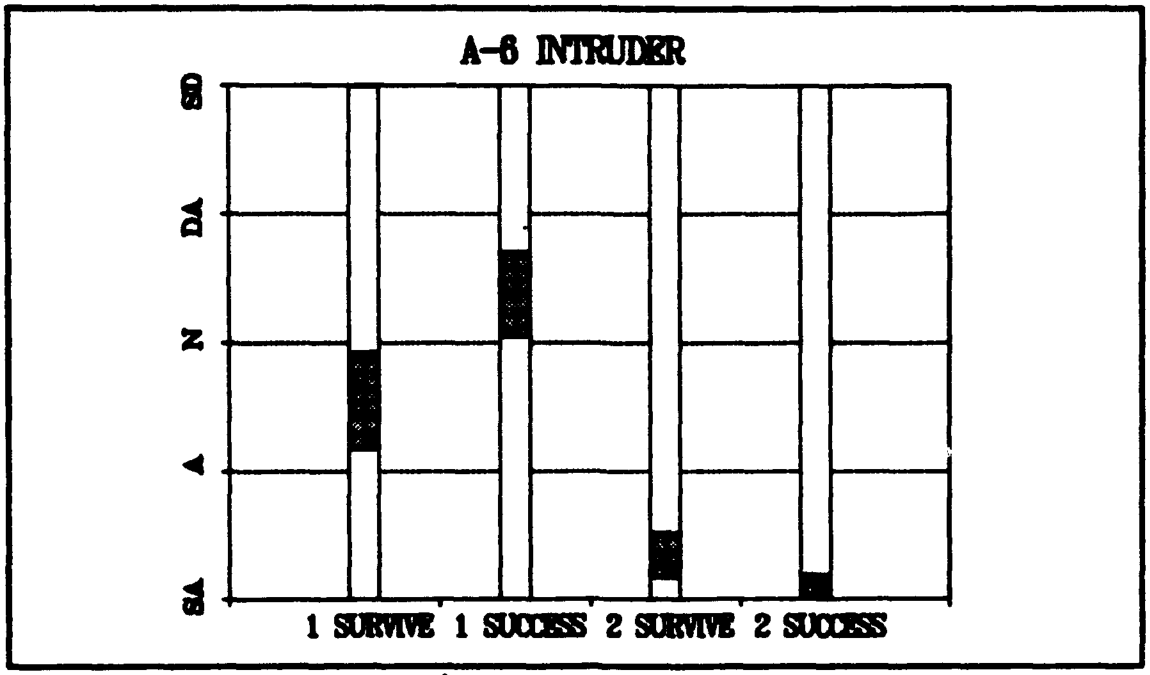

Figure 30. A-6 Pilots' Response to Close Air Support Questions in a Future Context

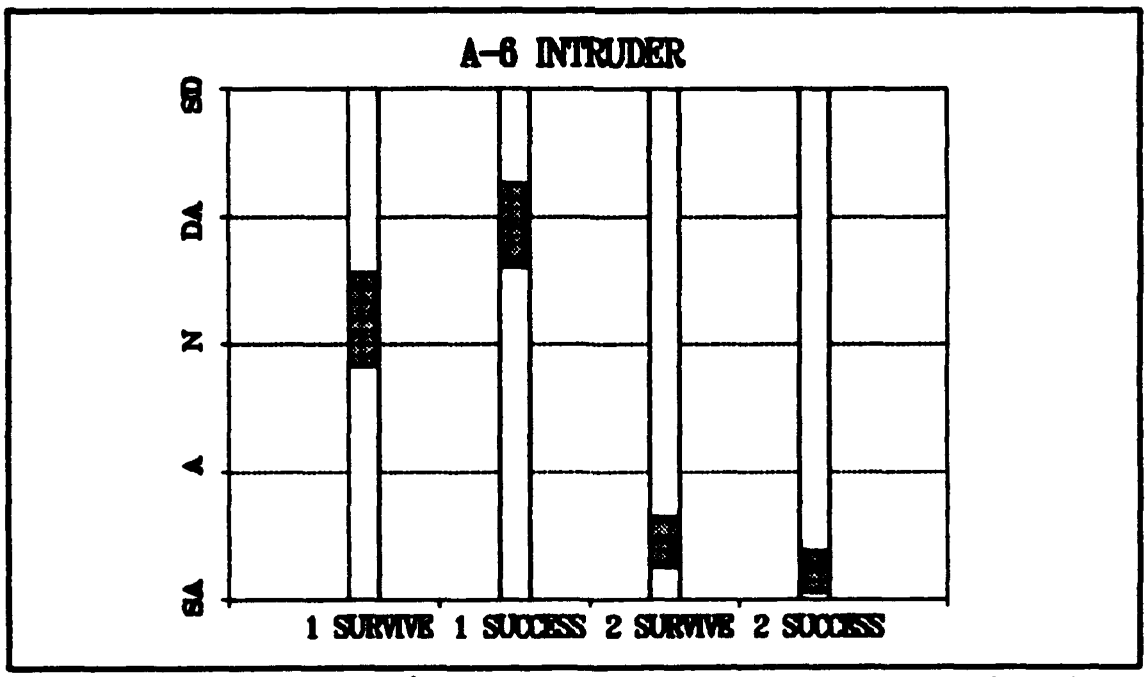

Figure 31. A-6 NFOs' Response to Close Air Support Questions in a Future Context

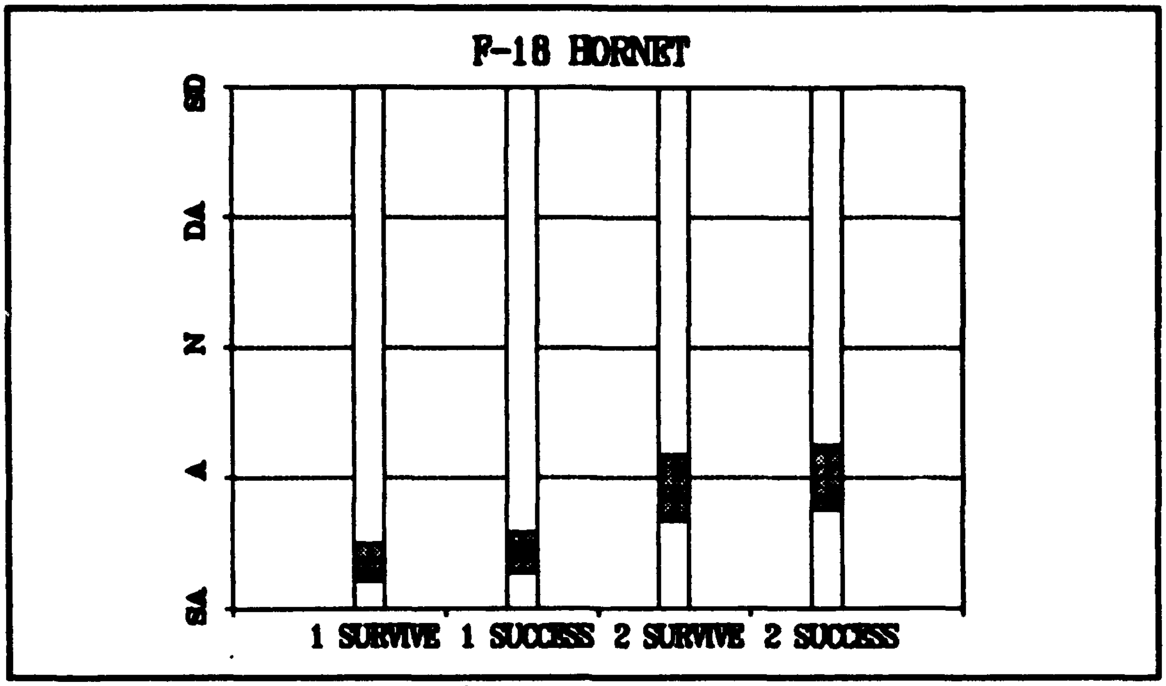

Figure 32. F-18 Pilots' Response to Close Air Support Questions in a Future Context

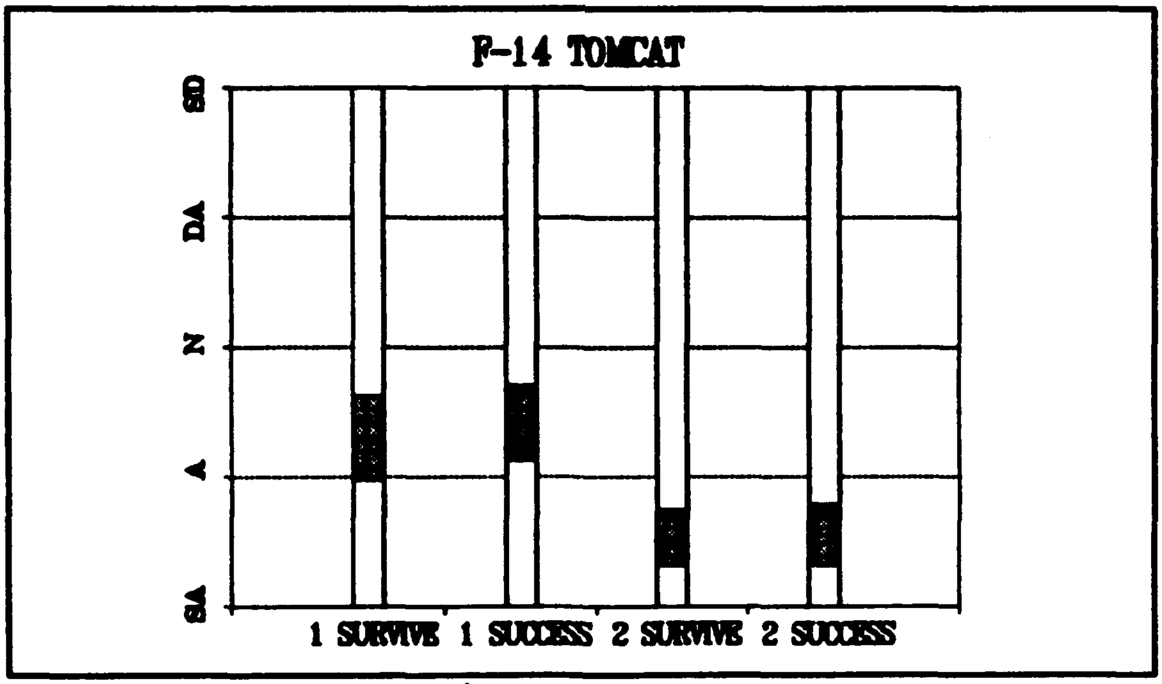

Figure 33. F-14 Pilots' Response to Close Air Support Questions in a Future Context

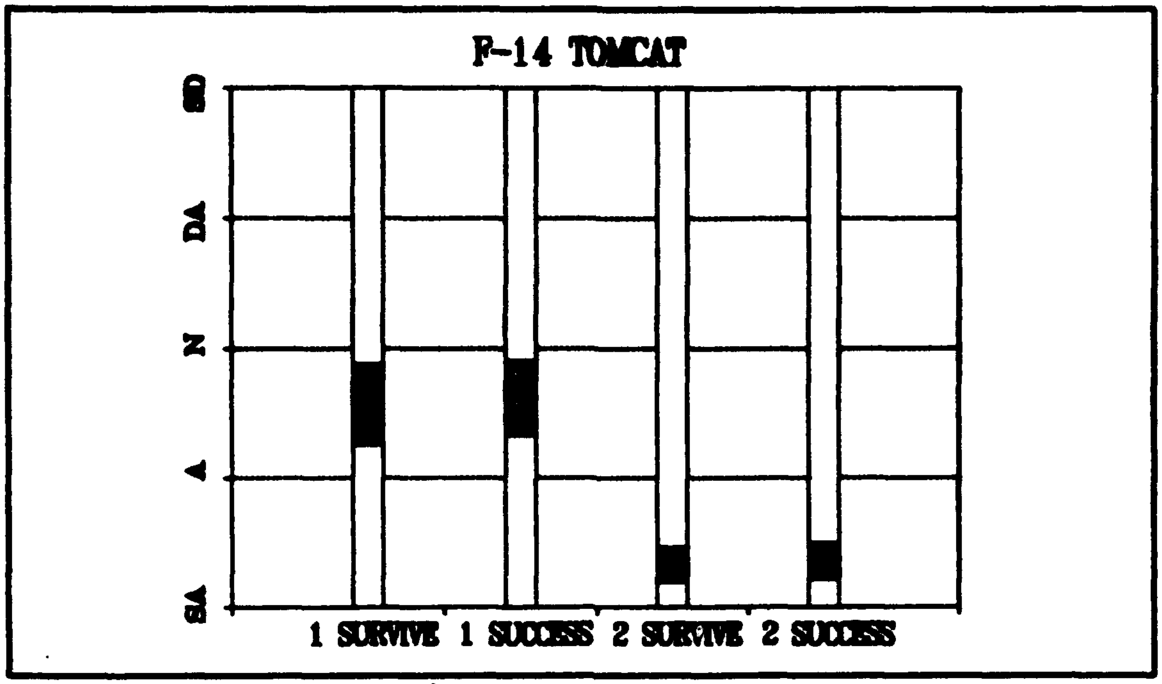

Figure 34. F-14 NFOs' Response to Close Air Support Question in a Future Context

Low/Medium Threat Interdiction

Aircrew responses indicate the low/medium threat interdiction (LT) mission to be relatively less demanding. The aircrew as a whole rate LT higher in capability for both single-seat and two-seat operations than the other four missions analyzed. The data below, and supporting graphs, indicate the highest level of confidence for one-seat operations. All four groups of aircrew indicated that success and survivability are probable in one-seat operations. The trend of two-seat success rated higher than two-seat survivability and single-seat success rated lower than single-seat survivability continues. The A-6 community as a whole still strongly supports two-seat operations, even in the low threat area. When compared to F-18 responses, A-6 crews

clearly present an opposite view point. Even when compared to F-14 responses, the A-6 responses differ substantially. The A-6 crews rate two-seat operations as highly survivable and highly successful, while noncommittal for survivability of single seat operations and negative on success rates. As mentioned above, the F-18 responses are fairly consistent with the previous categories in the low threat area. They have a high degree of confidence in both single-set and two-seat operations while again preferring single-seat operations. The F-14 community, while still an advocate of two-seat operations, gives single-seat low threat operations a good chance of survival and success. Even NFOs rate both survivability and success firmly on the agree side of the scale. Figures 35 through 40 present data for low threat interdiction.

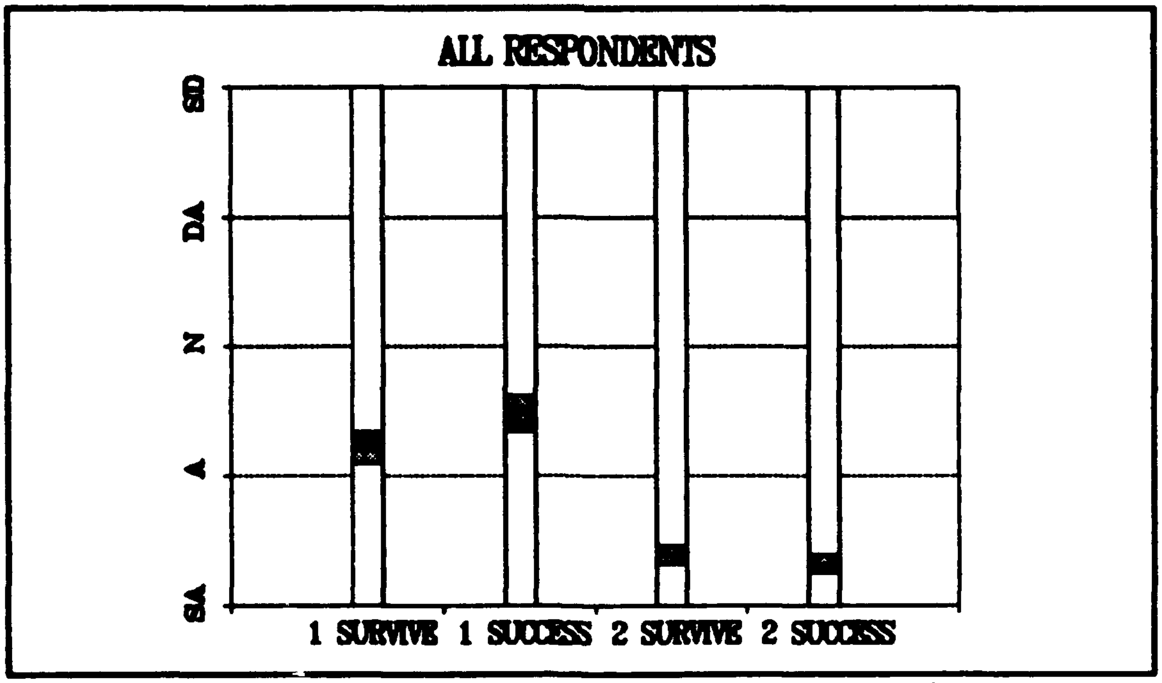

Figure 35. Combined Reply of All Respondents to Low/Medium Threat Interdiction Questions in a Future Context

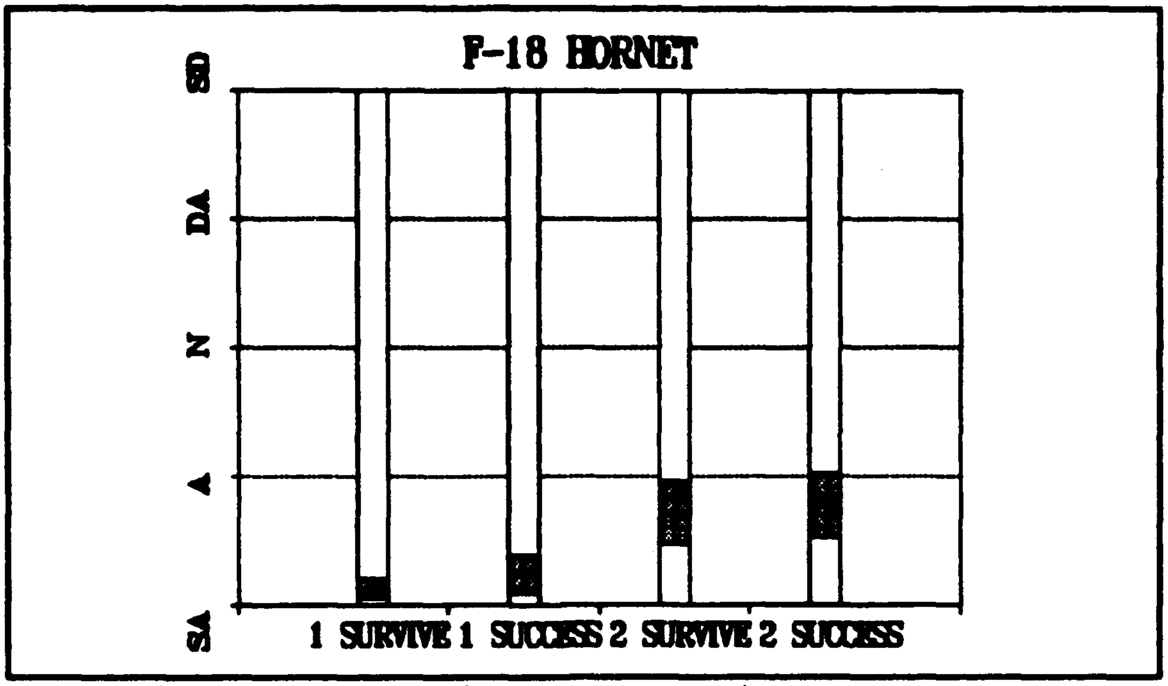

Figure 36. F-18 Pilots' Response to Low/Medium Threat Interdiction Questions in a Future Context

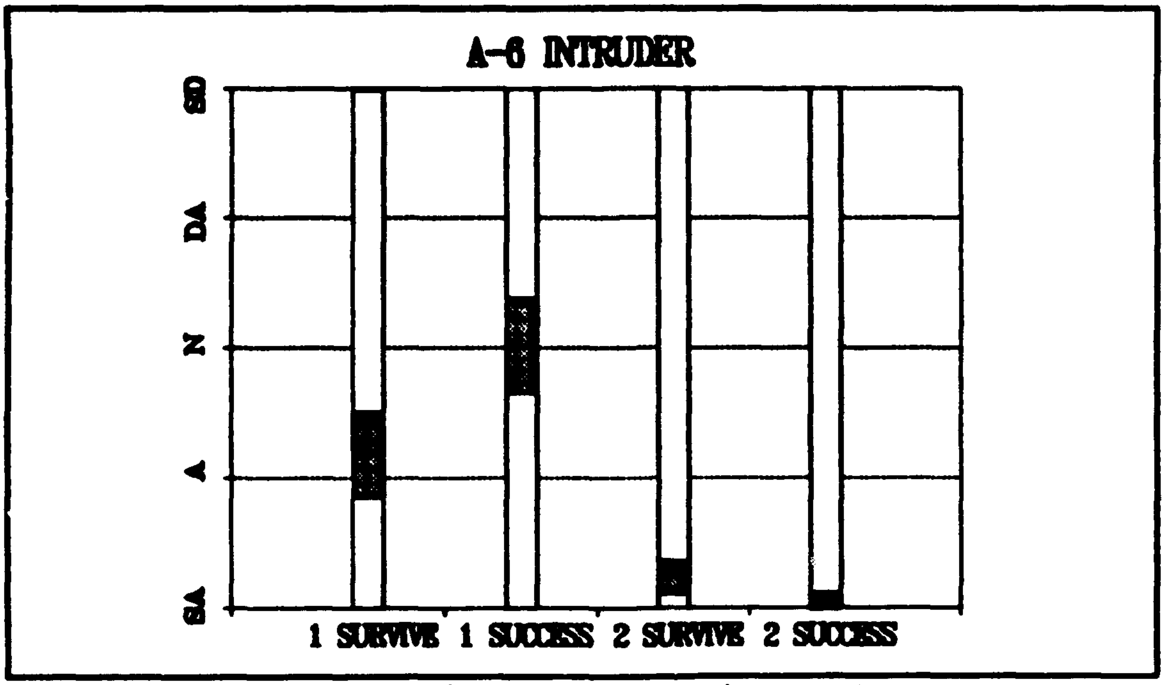

Figure 37. A-6 Pilots' Response to Low/Medium Threat Interdiction Questions in a Future Context

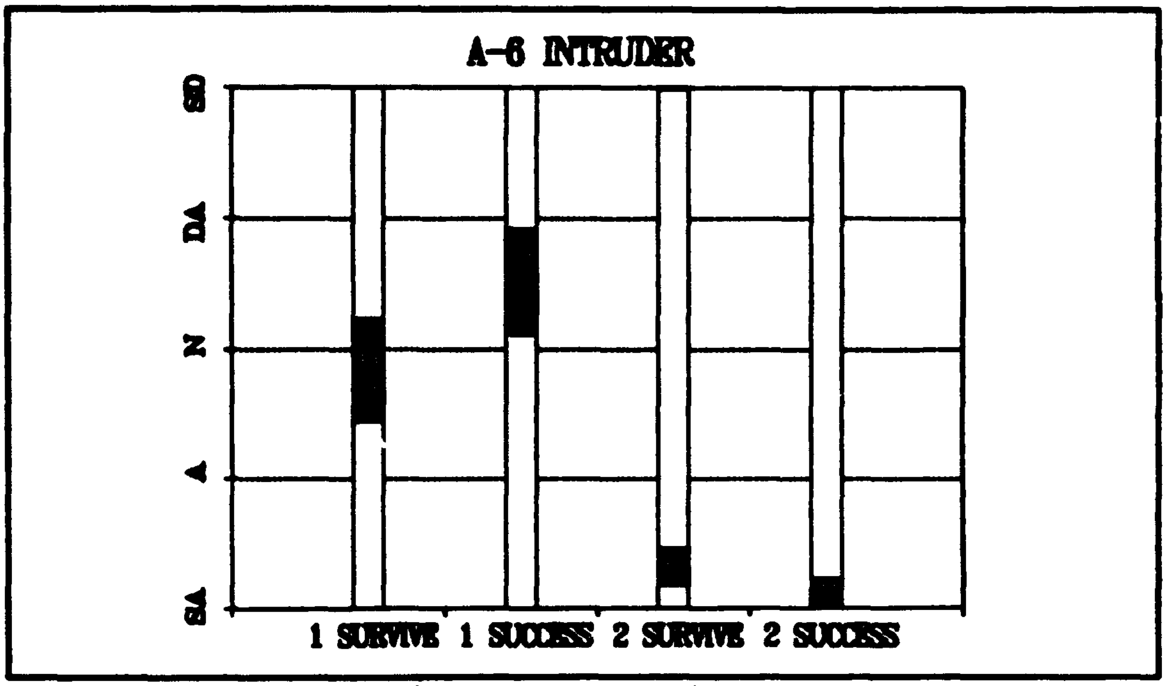

Figure 38. A-6 NFOs' Response to Low/Medium Threat Interdiction Questions in a Future Context

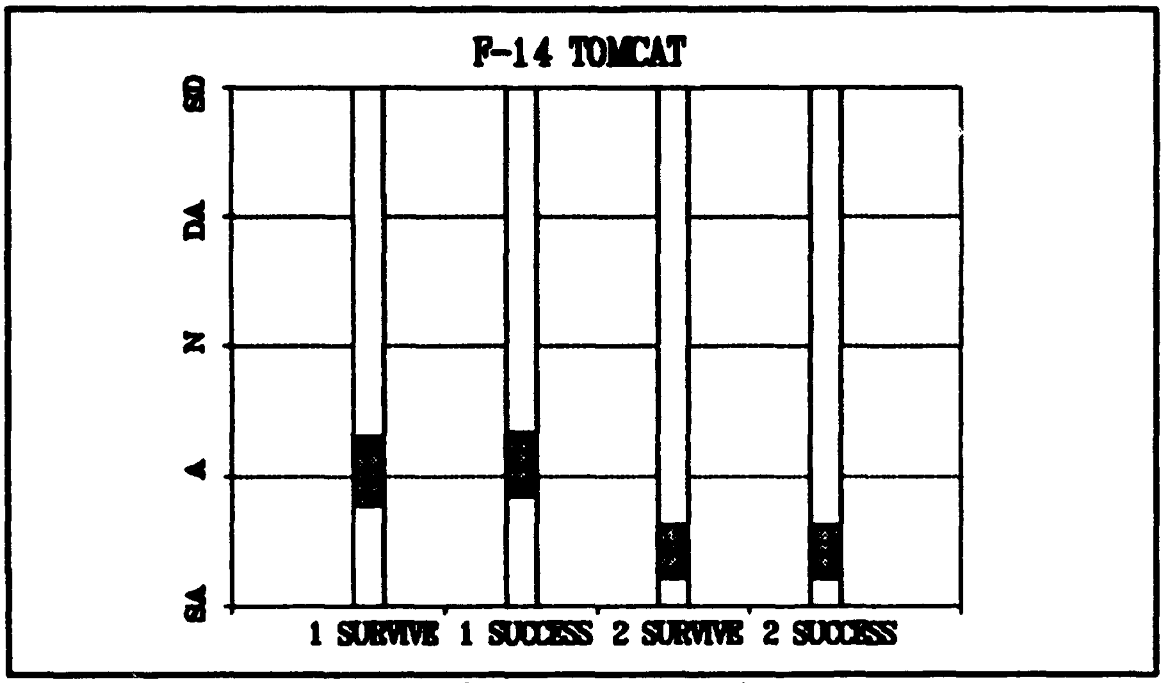

Figure 39. F-14 Pilots' Response to Low/Medium Threat Interdiction Questions in a Future Context

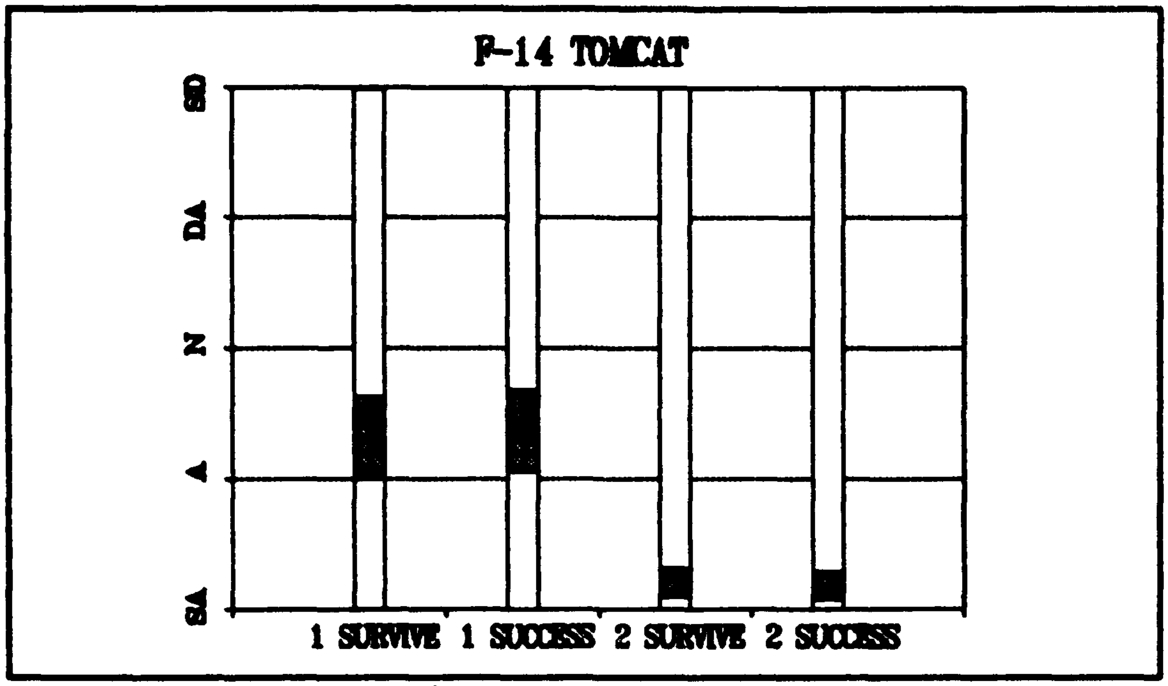

Figure 40. F-14 NFOs' Response to Low/Medium Threat Interdiction Questions in a Future Context

High Threat and Night /All-Weather Interdiction

The next two missions, high threat interdiction (HT) and night interdiction (NT) are similar in outcome and will be presented together. In these two mission areas a definite division forms in the data. Both the HT and NT missions see the F-18 community moving away from their strong preference for one-seat operations to a more neutral position. F/A-18 pilots do not indicate a statistically significant preference at the 90% level of confidence for one- or two-seat operations in the NT mission. For the HT mission, F/A-18 pilots are on the border of the 90% confidence level using the two-sample t test method. But when a paired t test is used, they still show a statistical preference for one-seat operations. On the other hand, both A-6 pilots and NFOs demonstrate a

significant preference for two-seat operations in both success and survivability for both the HT and NT missions. A-6 NFOs rate one-seat operations less capable than do their respective pilot counterparts. They also rate two-seat operations as slightly more capable than do A-6 pilots. Figures 41 through 48 serve to illustrate these findings.

While no illustrations are provided to highlight their responses, F-14 and EA-6 aircrews indicated a strong preference for two-seat operations for both these missions. This preference was statistically significant at the 90% confidence level and serves to reenforce the overall data presented in figures 41 and 45. The raw data can be found in Appendix C.

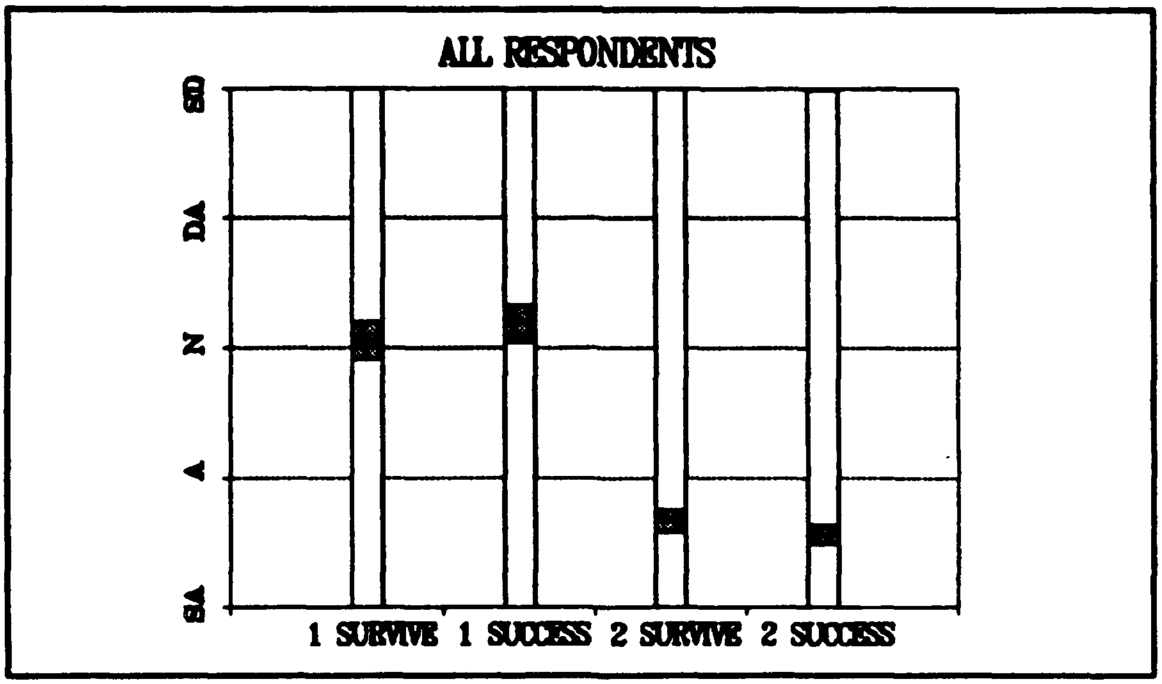

Figure 41. Combined Reply of All Respondents to High Threat Interdiction Questions in a Future Context

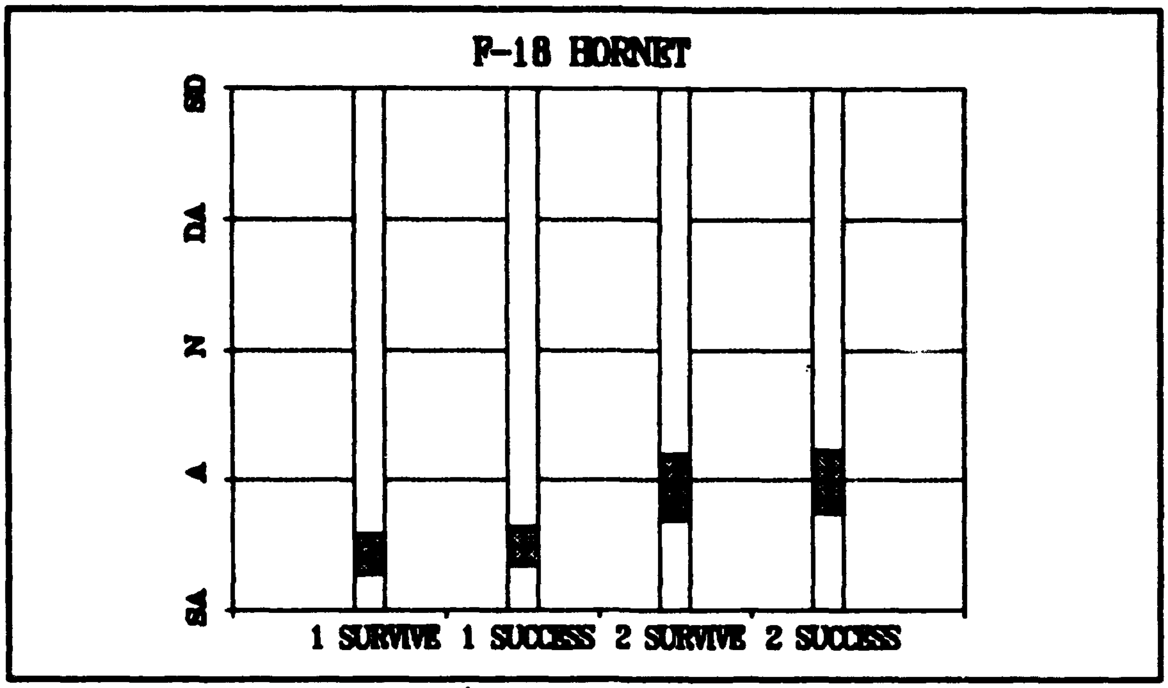

Figure 42. F-18 Pilots' Response to High Threat Interdiction Questions in a Future Context

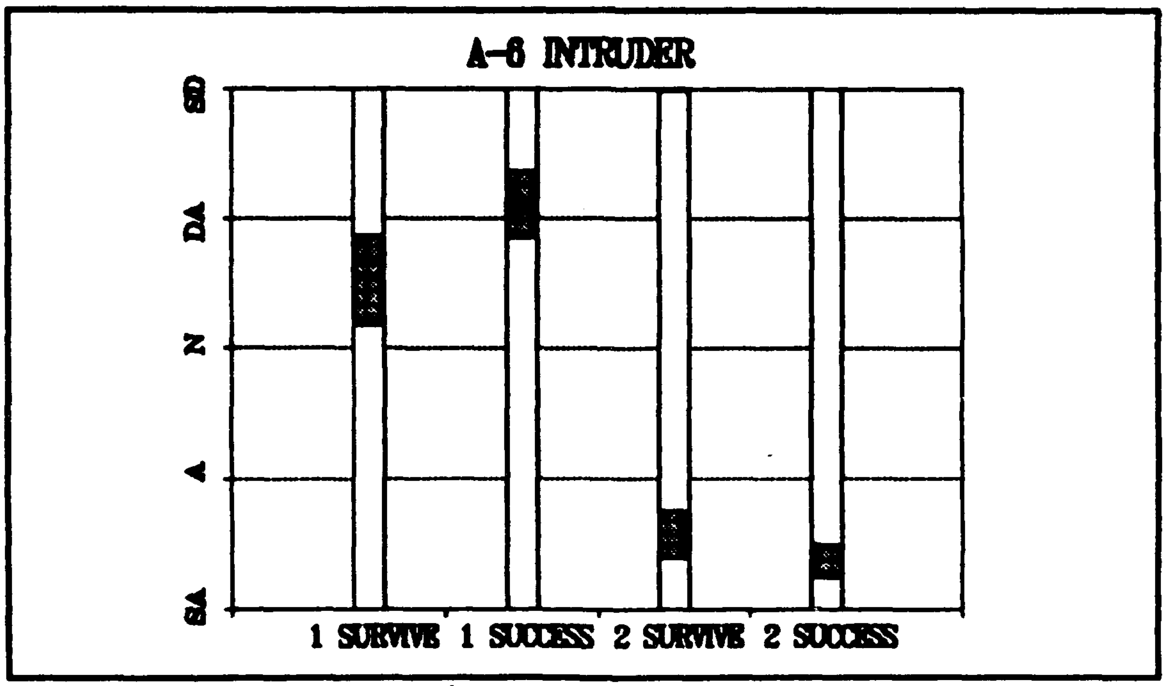

Figure 43. A-6 Pilots' Response to High Threat Interdiction Questions in a Future Context

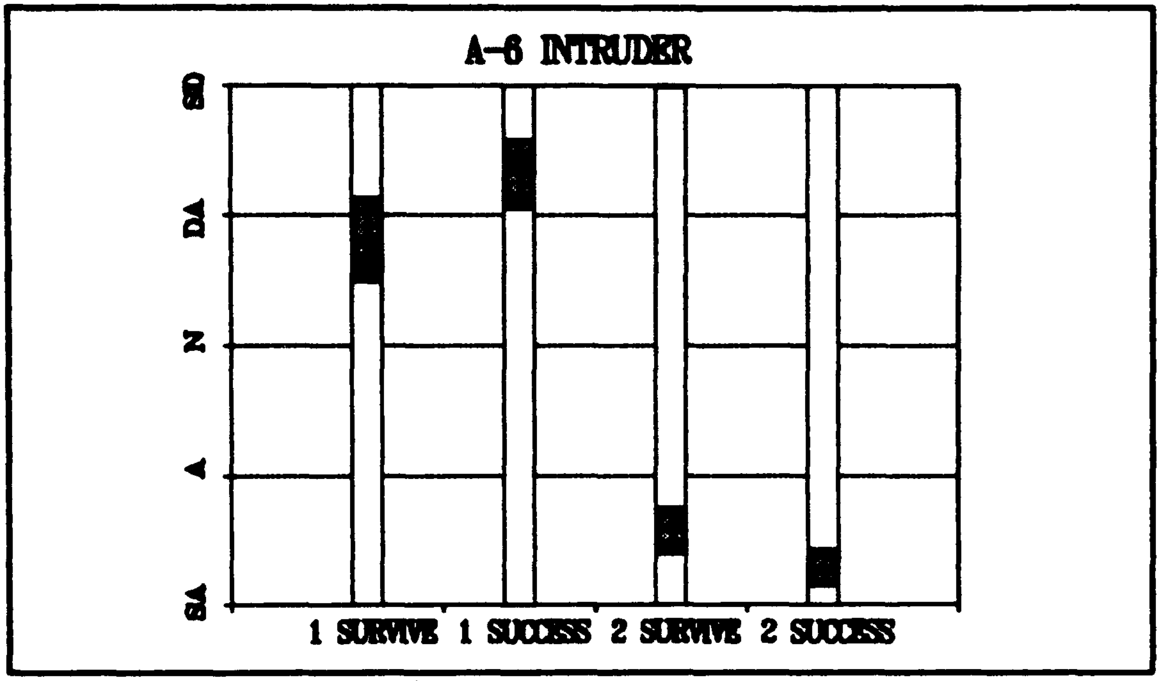

Figure 44. A-6 NFOs' Response to High Threat Interdiction Questions in a Future Context

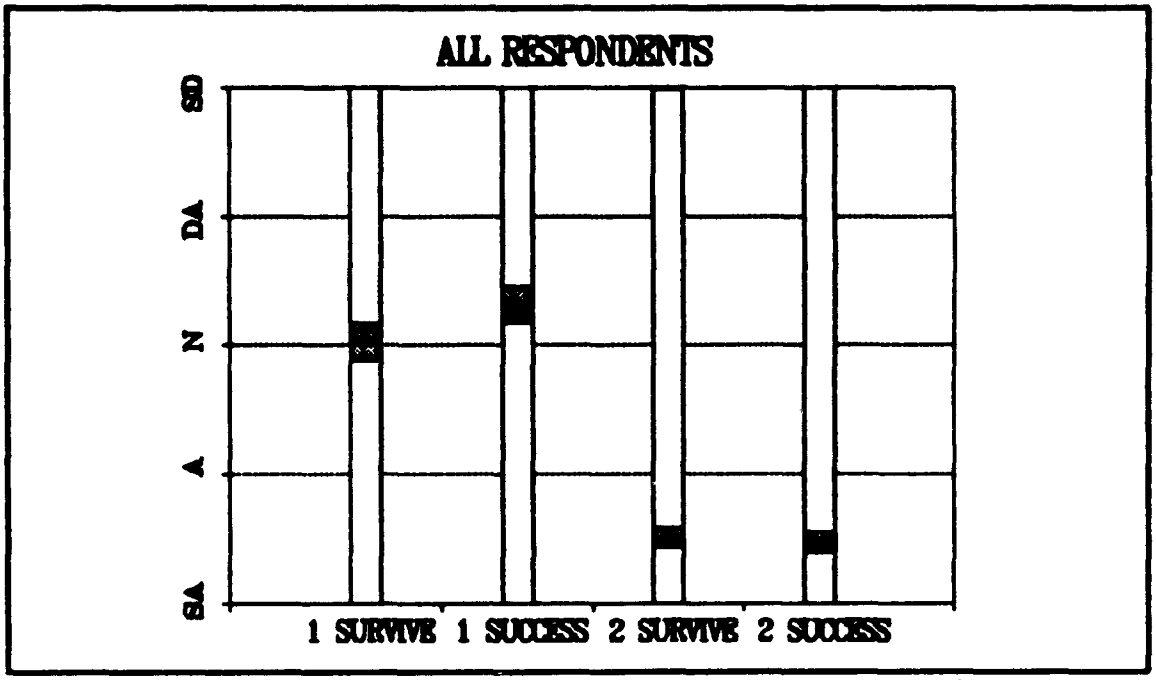

Figure 45. Combined Reply of All Respondents to Night/All-Weather Interdiction Questions in a Future Context

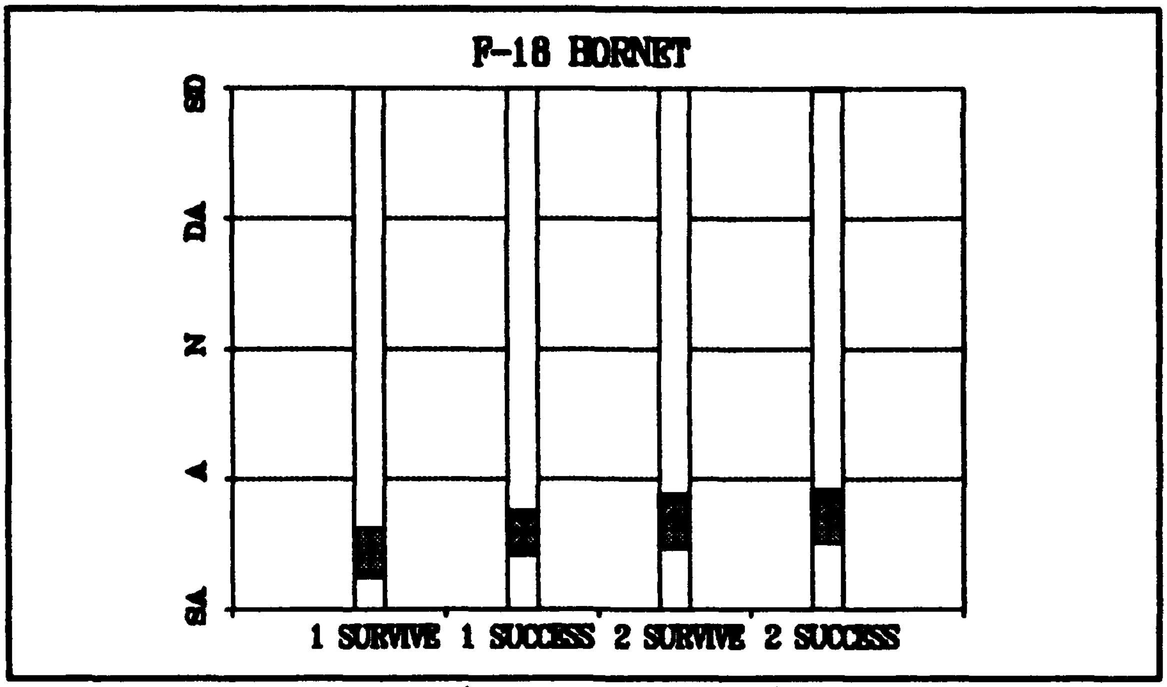

Figure 46. F-18 Pilots' Response to Night/All-Weather Interdiction Questions in a Future Context

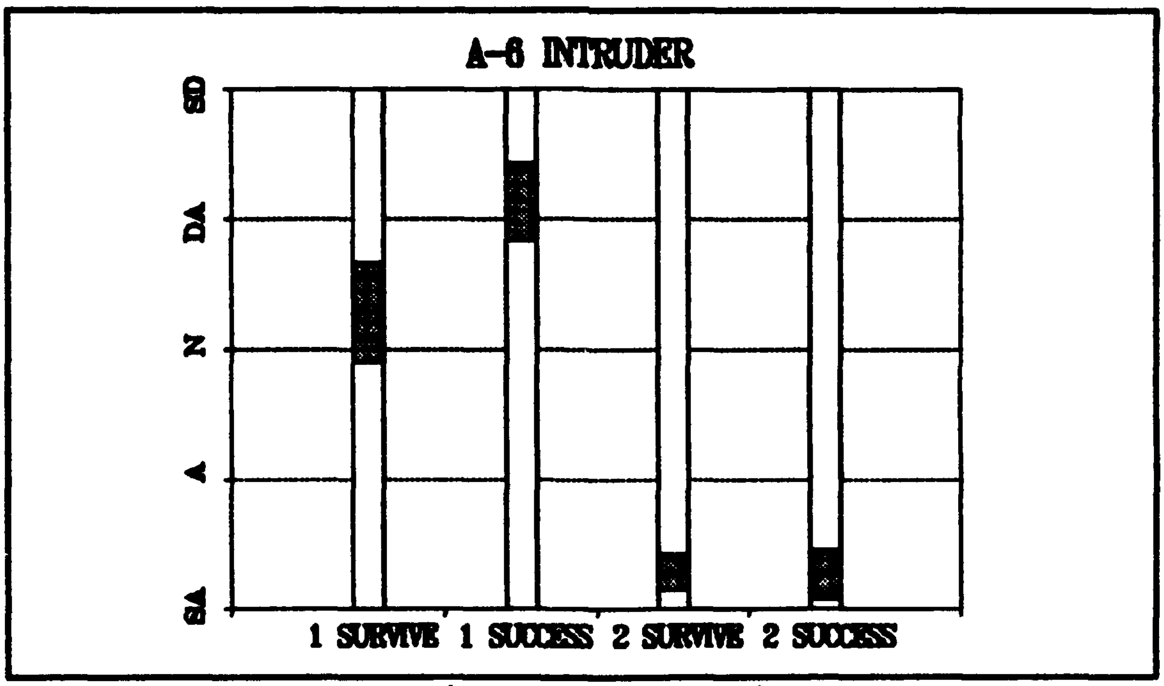

Figure 47. A-6 Pilots' Response to Night/All-Weather Questions in a Future Context

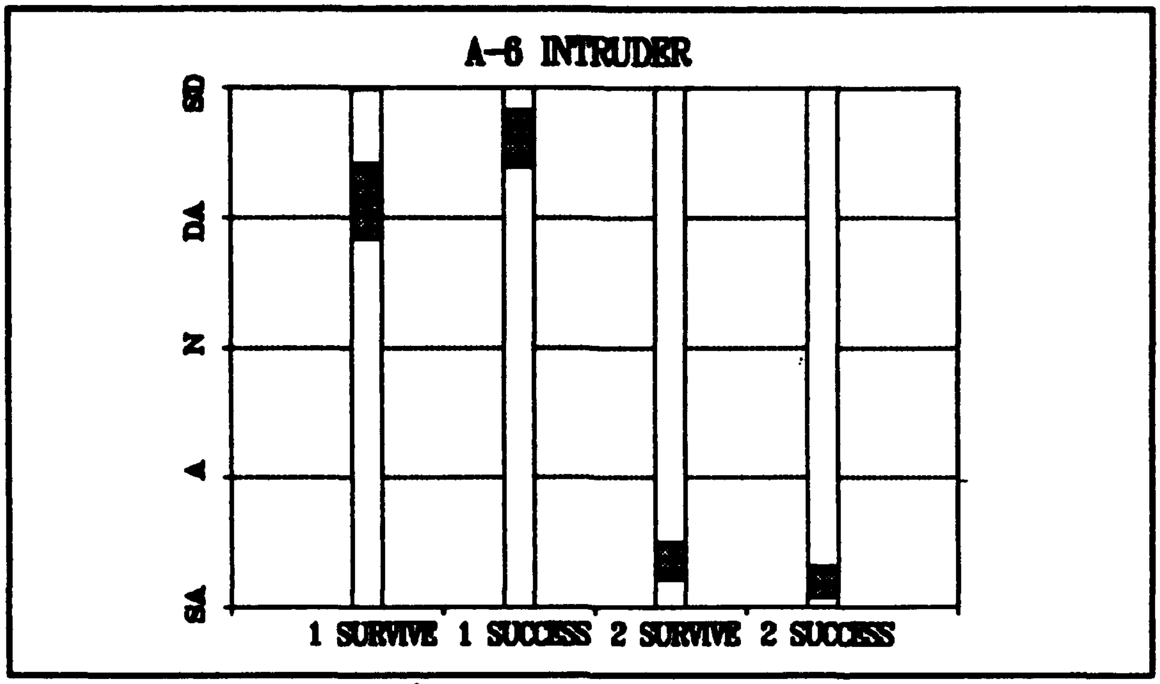

Figure 48. A-6 NFOs' Response to Night/All-Weather Interdiction Questions in a Future Context

Suppression of Enemy Air Defenses

The last mission area analyzed is suppression of enemy air defenses (SD). From an all aircrew perspective, SD is considered a relatively low threat mission, low workload mission when compared with all but LT. EA-6 aircrew who have this as a primary mission do not as a group concur with the overall results. SD is a primary mission for the EA-6B aircrew and secondary for the A-6 and F/A-18. The response patterns are similar to those in other missions. The overall data supports two-seat operations over single-seat operations, but still give single-seat operations a viable capability. Two-seat operations are given a high level of confidence. The overall interval for one-seat operations fell between slightly agree and neutral. A-6 aircrew data

indicates firm support for two-seat operations. There is little difference between A-6 pilot and NFO responses regarding two-seat capability. A-6 pilots give single-seat operations a limited degree of capability. A-6 NFOs are slightly less supportive. F-18 pilot responses were consistent with their responses in the majority of the other mission areas. They indicate support for one-seat operations, but give a substantial capability to two-seat operations. SD is a dedicated mission for the EA-6 aircrew. The EA-6B community, rates two-seat operations strong and single-seat operations poor. Both pilots and NFOs from the EA-6 responded with a high degree of agreement in their respective assessments. It is important to note that the EA-6 aircrew had to respond in the context of one- and two-seat operations. The EA-6 aircraft has a crew of four. The difference between the survey focus of one-seat and two-seat and the EA-6B's place as a four-seat aircraft is acknowledged as a potential confound and may explain why they were less confident for both one- and two-seat configuration than aircrew flying the A-6 and F/A-18. Figures 49 through 54 display graphical data for the SEAD mission.

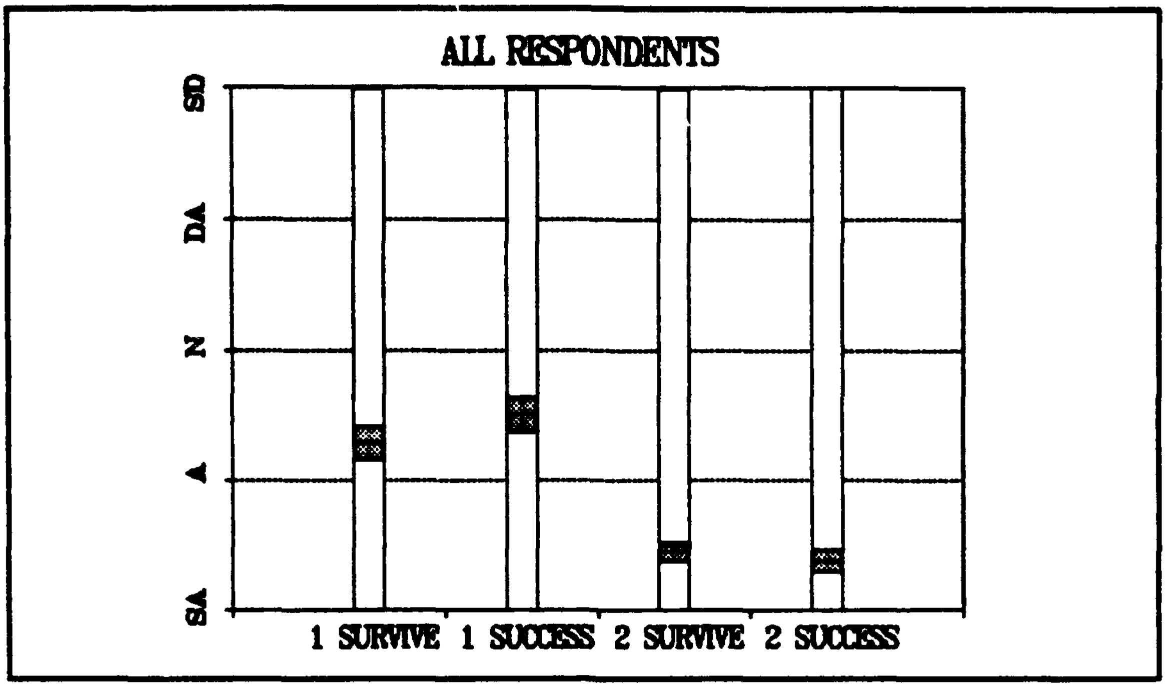

Figure 49. Combined Reply of All Respondents to Suppression of Enemy Air Defenses Questions in a Future Context

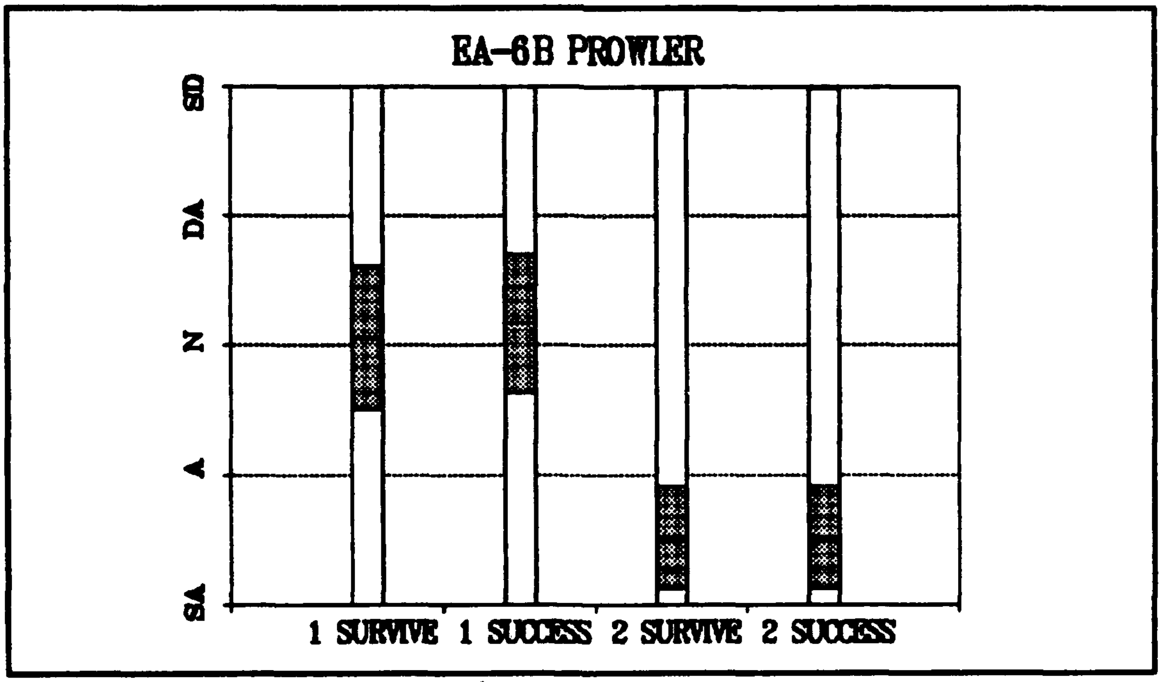

Figure 50. EA-6B Pilots' Response to Suppression of Enemy Air Defenses Questions in a Future Context

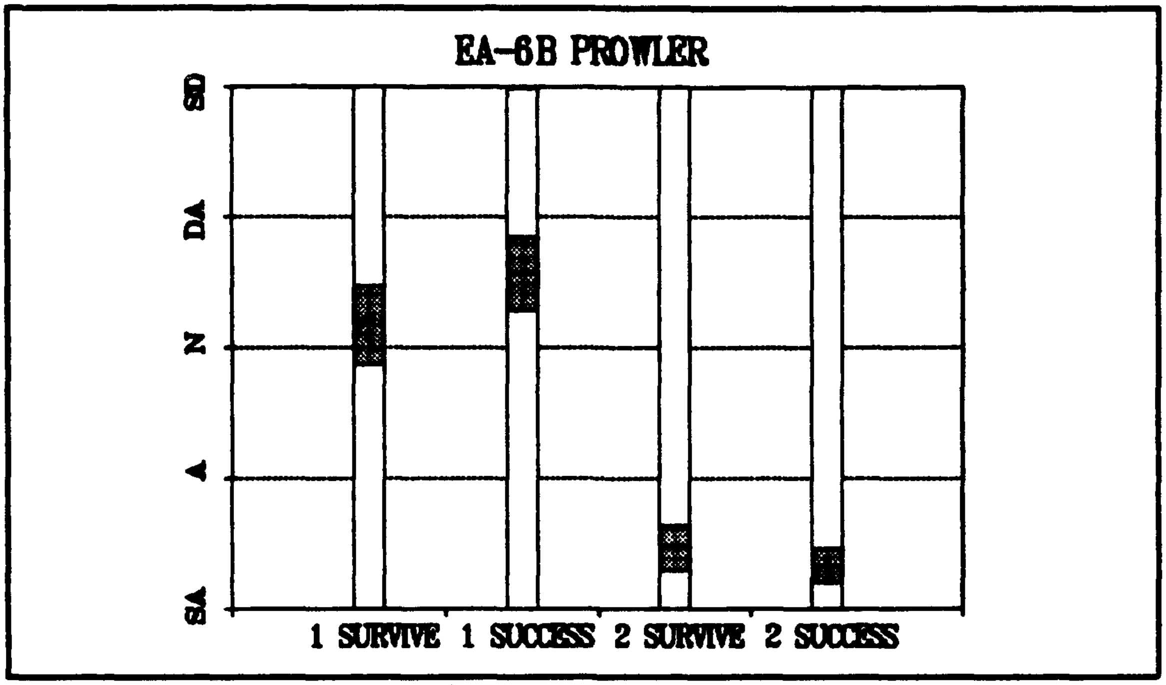

Figure 51. EA-6B NFOs' Response to Suppression of Enemy Air Defenses Questions in a Future Context

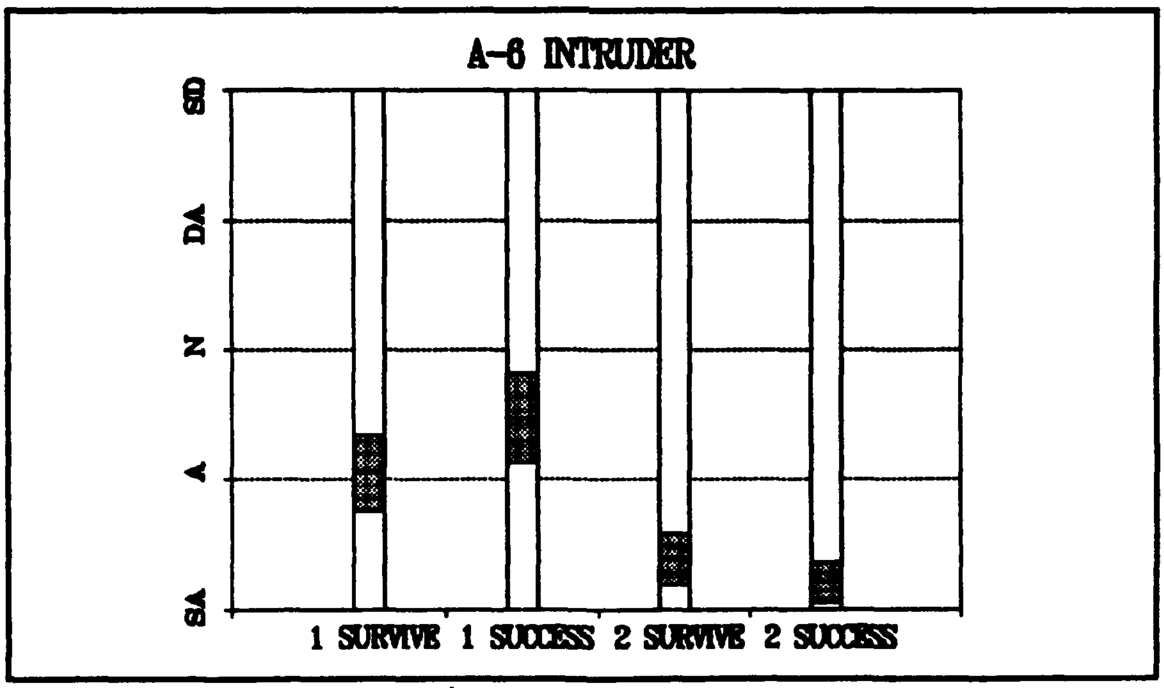

Figure 52. A-6 Pilots' Response to Suppression of Enemy Air Defenses Questions in a Future Context

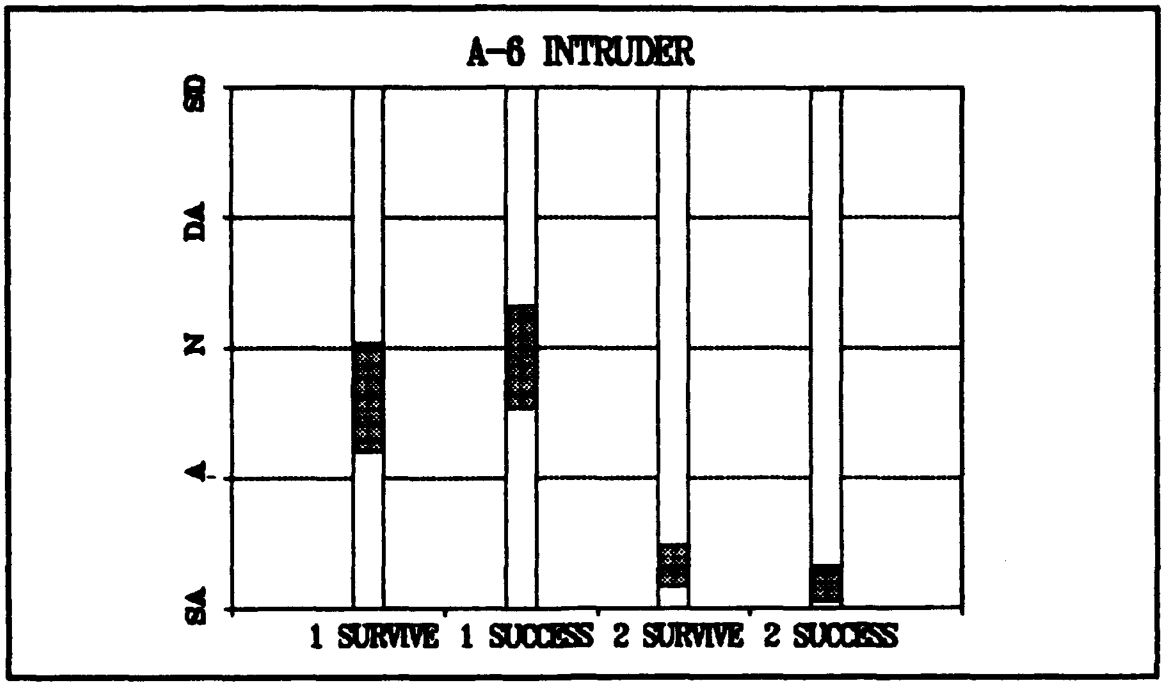

Figure 53. A-6 NFOs' Response to Suppression of Enemy Air Defenses Questions in a Future Context

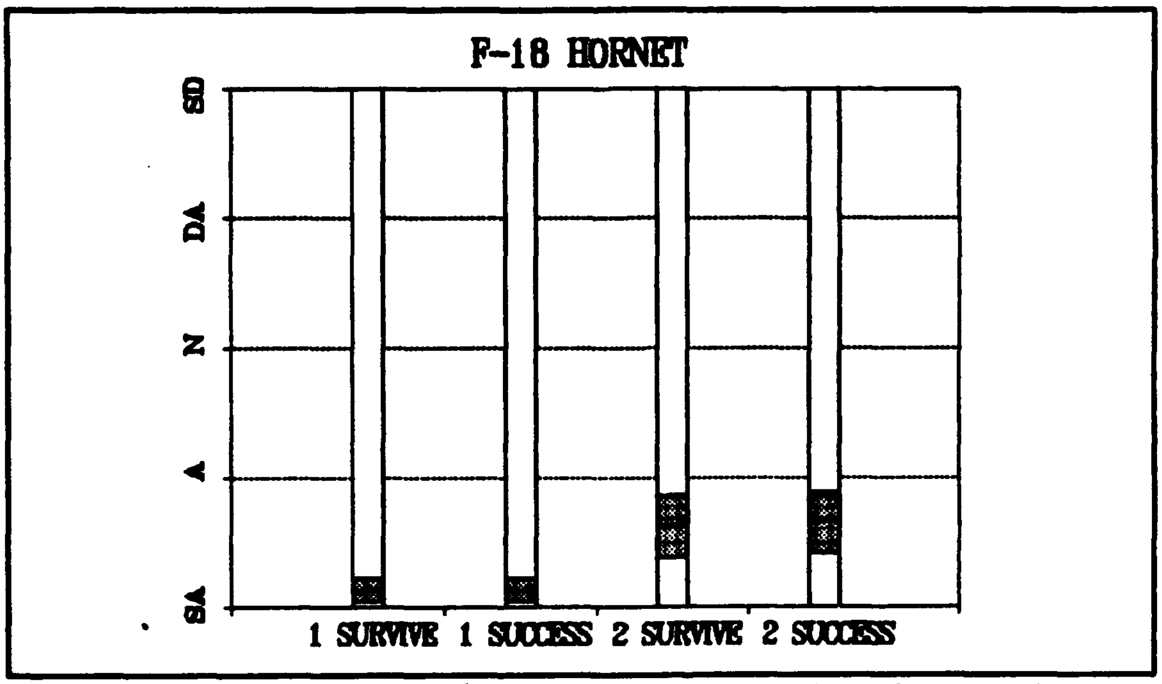

Figure 54. F-18 Pilots' Response to Suppression of Enemy Air Defenses Questions in a Future Context

Other Factors

A consistent theme witnessed in all mission areas for all aircraft was the tendency to support the status quo. Specifically, aircrew who had a particular mission as a primary mission tended to support that mission in the current configuration of their aircraft. An example is the F/A-18 responses in night/all weather interdiction (NT). The F/A-18 pilots frequently responded in the survey that five of the six missions were primary missions for them. The notable exception was NT. The majority of responses indicated only a secondary capability in this mission. As mentioned previously, the F/A-18 aircrew were less optimistic in this and high threat interdiction for both one- and two-seat configurations. Interestingly, they did not indicate that the addition of a crew member significantly improved capability. Both A-6 pilot and NFO data, on the other hand, strongly supported two-seat operations for the NT mission. The A-6 is a two-seat aircraft with NT as a primary mission.

F-14 pilot responses in the air superiority (AS) mission are an exception to the trend of defending the status quo. While preferring one-seat operations, they indicate one-seat operations to be survivable and successful. The measured difference in capability attributed to one- and two-seat operations is significantly smaller than that of their NFO counterparts. F-14 NFOs did rate one-seat operations as survivable and successful in the context of future aircraft. This topic will be discussed further in Chapter 5.

To further support a one- and two-seat analysis, paired t tests were performed to measure a statistical difference between various groups. The paired data is consistent with the graphical data already displayed. To summarize, A-6 pilots, A-6 NFOs, EA-6 pilots, EA-6 NFOs, F-14 pilots, and F-14 NFOs all statistically rate two-seat performance in terms of both survivability and success higher than one-seat performance. The two-seat preference passes the 90% confidence level test. In fact, for the three aircraft groups above, the majority of variables measured passed a 99% confidence level test as well. F-18 pilots, on the other hand, statistically rated one-seat operations better than two-seat operations in all mission areas except night interdiction survivability and night interdiction success. They rated these last two missions as statistically equal in capability at the 90% confidence level. Three categories (overall, all pilots, and all NFOs) statistically rated two-seat performance better than single-seat performance across all variables.

What is interesting to compare, however, is the percentage of respondents who rated single-seat operations equal in performance to two-seat operations. This data (see Table 6) establishes the same relationships as the graphical data above. It serves to further illustrate how perceptions are divided between pilots and NFOs. The data from the table indicates a higher number of pilots than NFOs give single-seat operations equal weight. Furthermore, a definite break-point exists between low and high threat/complexity missions.

TABLE 6

PERCENTAGE OF RESPONDENTS WHO RATE ONE-SEAT AND TWO-SEAT CAPABILITIES EQUALLY (BY MISSION)

MISSION VARIABLE	PILOT PERCENT	NFO PERCENT	OVERALL PERCENT
Survival Air Sup	49	26	48
Success Air Sup	33	22	28
Survival CAS	48	28	38
Success CAS	33	19	26
Survival Lo/Med Tht	51	31	41
Success Lo/Med Tht	35	24	30
Survival Hi Tht	37	12	25
Success Hi Tht	28	9	19
Survival Night	37	14	26
Success Night	29	9	19
Survival SEAD	55	35	45
Success SEAD	44	23	33

Up to this point, the analysis in this future has been largely categorical in nature. The rest of this chapter will illustrate some cross-category comparisons with an attempt to isolate factors along demographic lines other than aircraft type. Most of the data is not accompanied by a specific graph or table. For a detailed comparison of the data, refer to Appendix C.

The first comparison to be made is pilots to NFOs. Though much was revealed in the previous sections when compared by aircraft type, other findings will be presented. The following discussion is based on an extensive two-sample t test.

Of the 24 variables in the future section of the survey, the general trend between pilots and NFOs is that pilots statistically rate single-seat operations more capable than do NFOs. This is true for both

success and survivability. NFOs statistically rate two-seat operations more capable than do pilots for a specific mission. The exceptions to these two general rules follow. Pilots and NFOs agree (give generally the same ratings) in the following areas: two-seat survivability in CA, two-seat survivability in low/medium threat interdiction, two-seat survivability in high threat interdiction, two-seat survivability in night interdiction, and two-seat survivability in SD. While the listed exceptions are essentially statistically equal, they still follow the general rules as listed in all cases. Possible reasons for this division will be discussed in Chapter 5.

The next categorical analysis will compare aircrew with combat time to those without combat time. As a rule, there is no statistical difference in aircrew responses between those with and without combat time across the 24 variables in this section. This rule holds true for overall data, pilot data, and NFO data. There are, of course, exceptions and they will be discussed here.

Nine of the 24 variables in this section are judged statistically different in the overall category. Of these nine, eight reveal that those with combat time estimate that capabilities are better than those without combat time. In other words, aircrew with combat time are more confident than those without. The eight variables are: two-seat success in air superiority, two-seat survivability in low/medium threat interdiction, two-seat success in low/medium threat interdiction, two-seat survivability in high threat interdiction, two-seat success in high threat interdiction, two-seat success in night interdiction, two-seat

survivability in SEAD, and two-seat success in SEAD. The remaining variable, single-seat success in high threat interdiction, was rated as less capable by crew members with combat time than those without. These findings seem to indicate that there is little difference in the confidence levels of single-seat pilots based on combat experience. Conversely, two-seat crew members with combat time seem to be generally more confident than their counterparts without combat time.

The same analysis conducted specifically on pilots shows even less variance between pilots with combat time and those without. Of the 24 variables tested, only four showed a statistically significant difference between pilots with and pilots without combat time. Three of these four variables reveal that pilots with combat time think they have a better capability in the mission than those without combat time. The three mission variables that pilots with combat time rank as more capable are: two-seat success in CAS, two-seat success in low/medium threat interdiction, and two-seat success in high threat interdiction. The lone variable that pilots with combat time rate less capable than those without combat time is high threat interdiction. One-seat high threat interdiction is rated less capable than two-seat. The data suggests that for pilots, combat time has little influence on confidence levels for survivability and success.

Analysis between NFOs with combat time and NFOs without combat time reveals that six of the 24 variables tested showed a statistically significant difference between the two groups. All six of the differing variables show that NFOs with combat time rate the capability in

question better than those without combat time. The variables are: two-seat survivability in low/medium threat interdiction, two-seat success in low/medium threat interdiction, two-seat success in night interdiction, single-seat survivability in SEAD, two-seat survivability in SEAD, and two-seat success in SEAD. The data here seems to support the overall findings from above. Again, if combat time is an influence, it tends to be manifested in a feeling of more self-confidence. Except for single-seat high threat success from above, all trends point to this same conclusion. Combat time also tends to influence the opinions of NFOs more than pilots.

An attempt was made to determine if a position of relative authority in the squadron affected the opinion of the crew member. Those who were FRS instructors or NATOPS checkers were separated from the general population and compared to those who were not FRS instructors or NATOPS checkers. At the 90% confidence level, none of the 24 variables tested were found to be different based on this categorization. This data may indicate that the people in the responsible positions are successful in conveying their attitudes to trainees, or that there is no relationship that can be drawn along this category line.

Finally, an attempt was made to determine if a respondent's rank or flying time helped shape his opinions. As mentioned previously, strong correlation between rank and flying time was found to exist. The analysis that follows is based on rank. Conclusions based on this categorization also apply to an analysis based on flying time.

The demographics paragraph at the front of this chapter shows the breakout of the sample by rank. Analysis of this table reveals that no O-1s and two O-6s responded to the survey. The analysis, therefore, centers on O-2 through O-5. Due to problems associated with direct comparisons in a multi-sample environment, this analysis is qualitative. The objective of this analysis is to explore any overall trends in the data between aircrew as experience level varies.

There is a definite trend (variation) in responses as rank increased. For single-seat operations, as rank increased, the perceived capabilities also increased. In all categories of single-seat operations except success in night interdiction, O-2s rated capabilities lower than did O-5s. In success of night interdiction, O-4s rated single-seat operations slightly worse than O-2s.

For two-seat operations, no significant correlation between rank and perceived success rate was noticed. In most cases, O-2s rated two-seat operations less capable than did the other grades, but the differences are not statistically significant.

Though respondents with more rank, and hence more experience, tended to rate one-seat operations in a more favorable light than those with less, the overall picture is consistent with the findings to this point. It is noteworthy that in the night and high threat interdiction missions, the senior officers display a higher confidence in single-seat operations than do their lower ranking counterparts. This support is only of a relative nature. The absolute rating is at best only weak support for these one-seat missions.

The Effect of Technology on Crew Workload

The third section of analysis measures how aircrew thought technology would affect overall workload in the context of our next generation fighter. Six questions are asked to specifically analyze how the addition of new technology affects aircrew workload. Responses by aircrew with no experience in a particular mission are largely speculative. Aircrew flying aircraft equipped with later technology have a stronger experience base on which to base their responses.

The common frame of reference for comparison is a next generation tactical aircraft. The six variables measured all come from section two of the survey. The technology variables were divided along the same lines as survivability and success and measure perceived technology contributions to the decrease of work load. Responses on the agree side indicate that the respondent agrees that technology will reduce workload. Responses on the disagree side indicate that the respondent disagrees that technology will reduce workload. Similar analysis to the previous sections on current and future variables is accomplished. For ease of direct comparison, all six variables appear on each graph. All crew position/aircraft type categories are presented along with an overall, pilot, and NFO categories. Appendix C contains the raw data used to generate the graphs. Table 7 contains a list of variables.

TABLE 7

LIST OF VARIABLES MEASURED IN TECHNOLOGY SECTION

VARIABLE	EXPLANATION OF VARIABLE MEANING
TAS	Technology in the air superiority mission
TCA	Technology in the CAS mission
TLT	Technology in the low/medium threat interdiction mission
THT	Technology in the high threat interdiction mission
TNT	Technology in the night interdiction mission
TSD	Technology in the SEAD mission

Analysis of the overall data reveals that the Navy believes technology will reduce workload to some degree in all six mission areas. The greatest reductions in workload will occur in the low/medium threat interdiction mission and the SEAD mission. The graph containing pilot data seems to parallel the above findings. It also indicates that pilots expect a more measurable reduction in workload due to technology improvements than the population as a whole. NFOs, on the other hand, display less confidence in future technologies as they relate to workload. The data indicates that they expect the workload to stay about the same in the future as it is today. The data is presented in Figures 55 through 57.

The form of these graphs is slightly different than that of the previous two sections. All six variables for technology are contained on a single graph. The responses, in the form of confidence intervals, represent the degree to which respondents think technology will reduce overall workload. The graph headings indicate which specific group of

respondents are represented by aircraft and crew position. The ordinate axis is identical to the form already displayed in the previous sections' graphs, displaying a scale ranging from strongly agree, at the bottom, to strongly disagree, at the top.

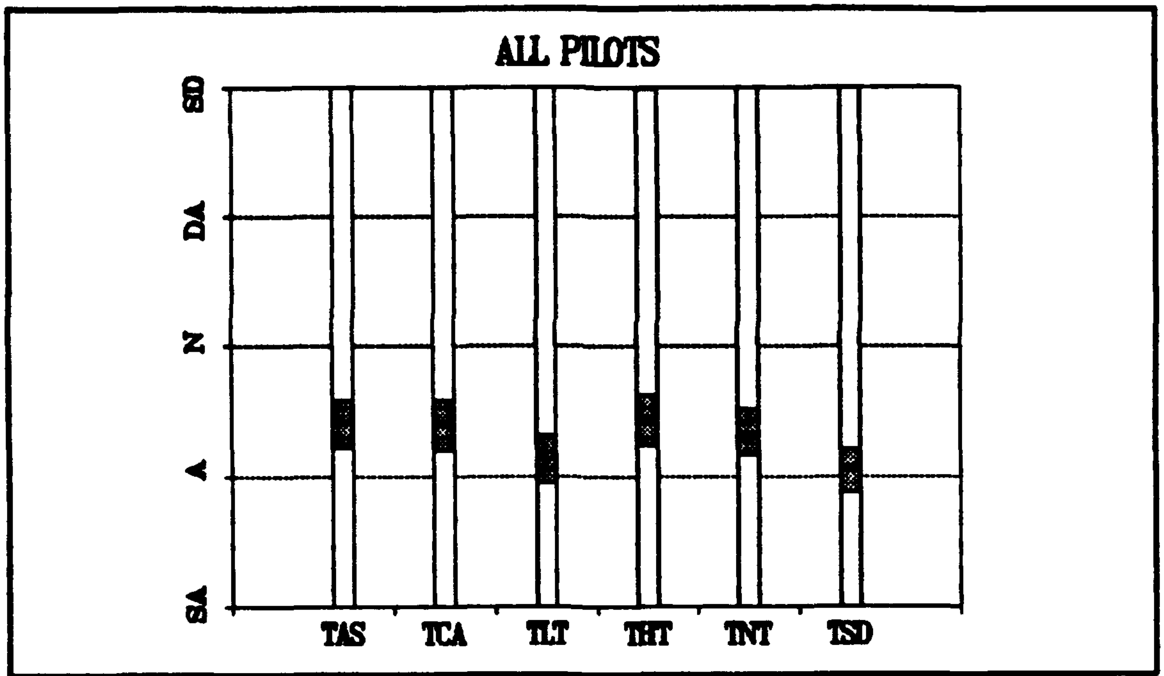

Figure 55. Combined Reply of All Pilots to Technology's Effect on Aircrew Workload for All Six Missions Measured

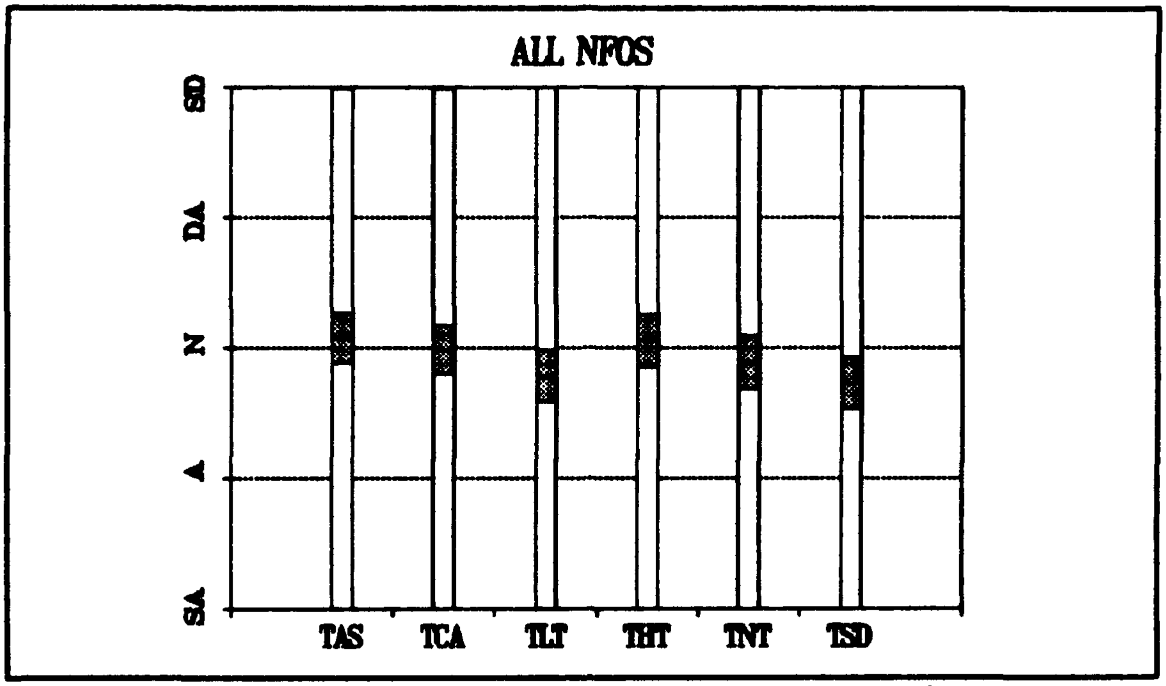

Figure 56. Combined Reply of All NFOs to Technology's Effect on Aircrew Workload for All Six Missions Measured

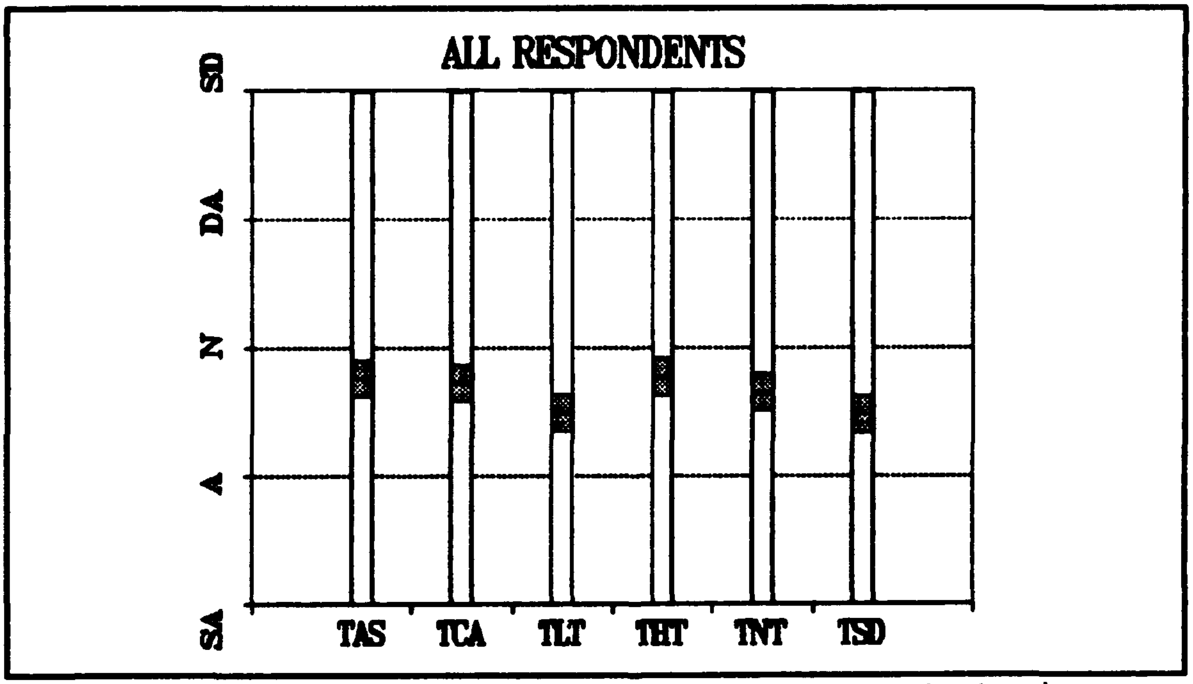

Figure 57. Combined Reply of All Respondents to Technology's Effect on Aircrew Workload for All Six Missions Measured

The next series of graphs (Figures 58 through 64) present the technology data for crew positions in each of the four aircraft. The graphs follow the patterns established in the above pilot and NFO categories with few exceptions. EA-6 NFOs display a pattern more representative of the overall pilot graph than the NFO graph. F/A-18 pilots display high confidence that technology will reduce workload in all mission areas. F-14 pilots and NFOs contain noticeable disagreements (pilots expecting more workload reduction than NFOs) while A-6 pilots and NFOs have similar opinions. Two sample t tests designed to measure statistical differences between pilot responses and NFO responses confirm that for all six variables, pilots expect a greater workload reduction due to technology improvements than do NFOs.

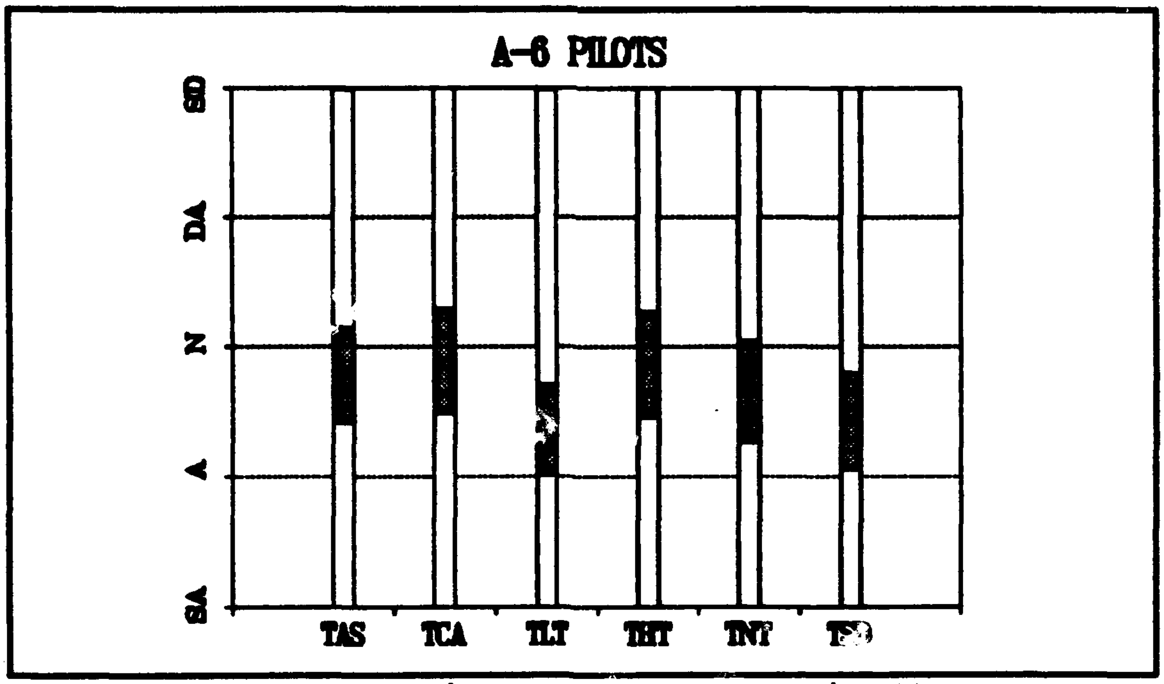

Figure 58. A-6 Pilots' Response to Technology's Effect on Aircrew Workload for All Six Missions Measured

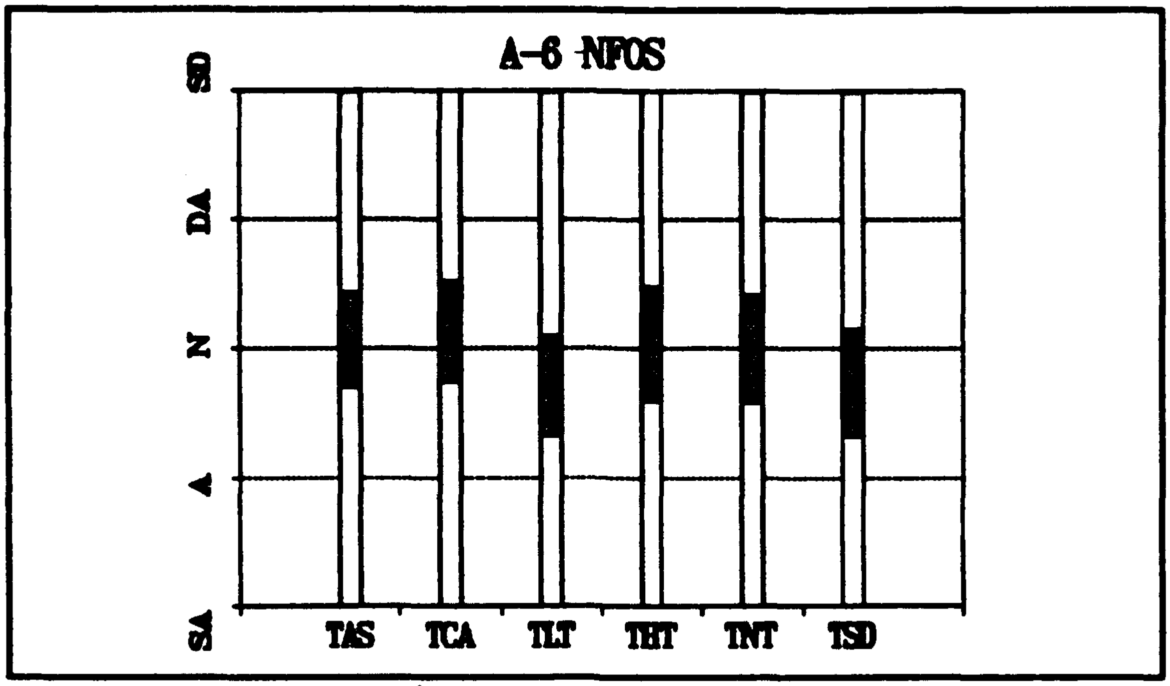

Figure 59. A-6 NFOs' Response to Technology's Effect on Aircrew Workload for All Six Missions Measured

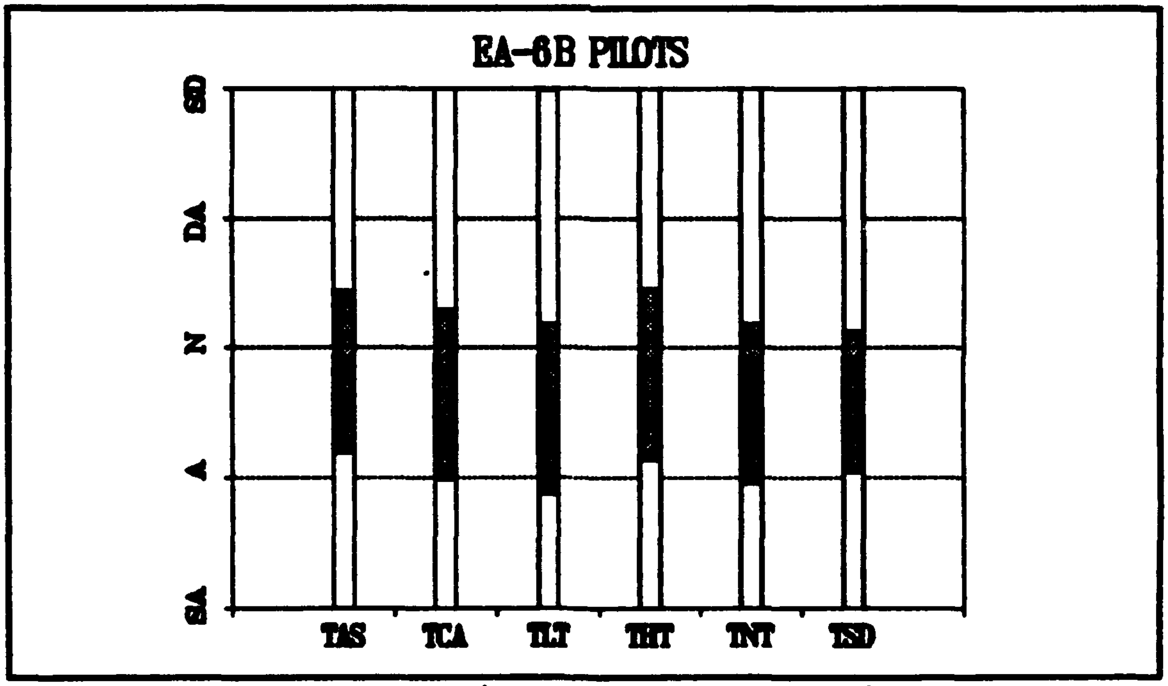

Figure 60. EA-6B Pilots' Response to Technology's Effect on Aircrew Workload for All Six Missions Measured

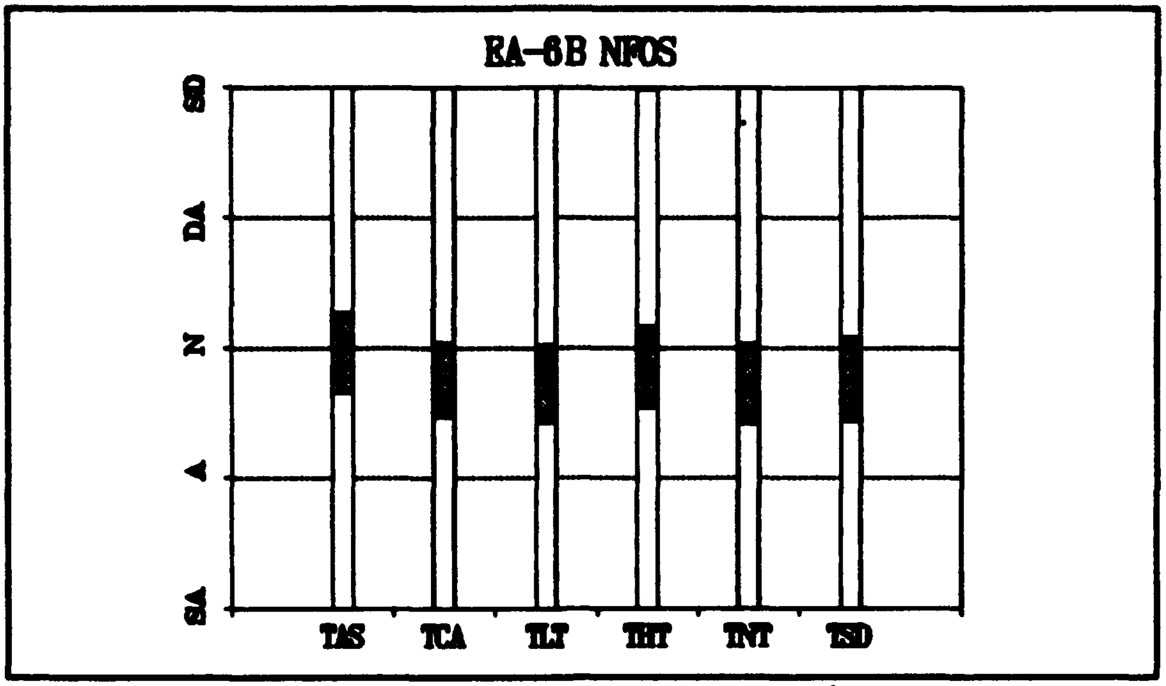

Figure 61. EA-6B NFOs' Response to Technology's Effect on Aircrew Workload for All Six Missions Measured

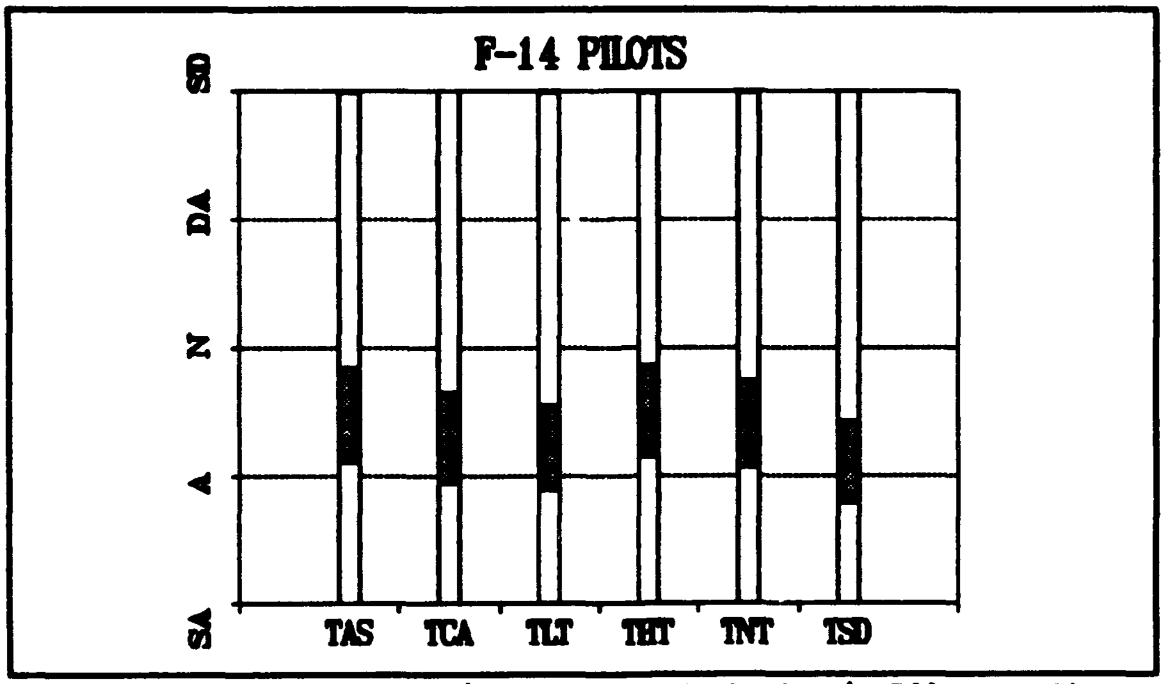

Figure 62. F-14 Pilots' Response to Technology's Effect on Aircrew Workload for All Six Missions Measured

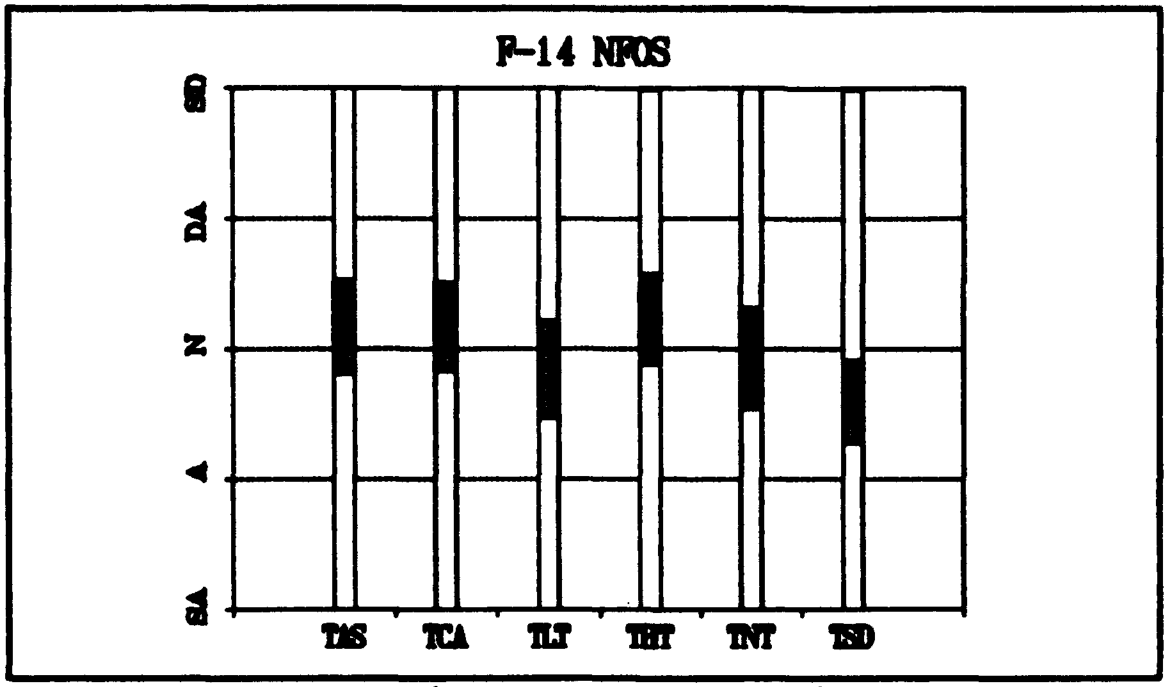

Figure 63. F-14 NFOs' Response to Technology's Effect on Aircrew Workload for All Six Missions Measured

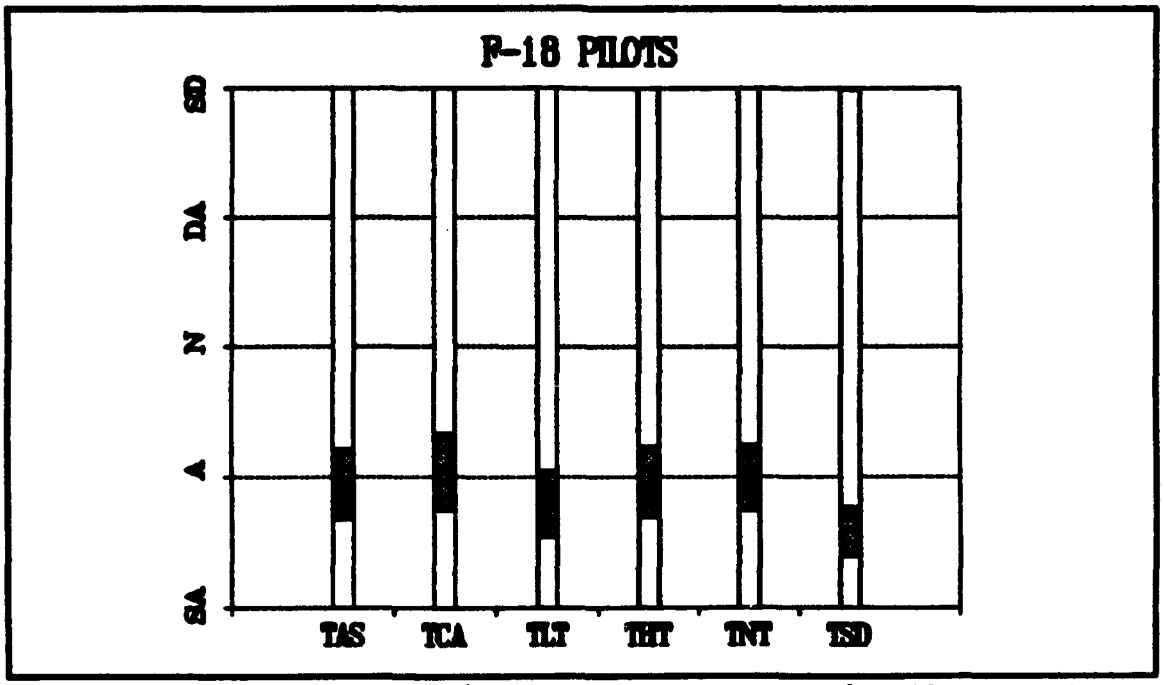

Figure 64. F-18 Pilots' Response to Technology's Effect on Aircrew Workload for All Six Missions Measured

In addition to a pilot-NFO comparison, other tests were performed. As in the previous section, a two sample t test was run to measure differences of opinion regarding whether or not the respondent had combat time. The test of the overall data set reveals that for all categories except SD, those with combat time indicated that workload would be reduced to a lesser extent than those without combat time. In other words, people with combat time are less confident that workload can be reduced by introducing new technology. For SD there was no statistical difference between combat and no combat responses. Interestingly, when the same test was run on pilots and NFOs individually, the results were quite different. In the pilot category, no statistical difference between those with and without combat time surfaced in any of the six technology variables. NFOs only revealed a difference in the air superiority and low/medium threat interdiction areas. These conflicting pieces of information may suggest that there is not a strong relationship between combat time and an opinion about how technology affects workload. It is significant to note, however, that even though a statistical difference between combat and noncombat responses did not exist in 10 of the 12 categorical sub-groupings above, all of the 12 variables exhibited tendencies toward the position established by the overall data. Had the confidence level been set at the 80% level, for example, a much stronger correlation would have been established.

The same t test was performed on FRS instructors and NATOPS checkers. They were compared to those without this designation. No

statistical differences between the groups were detected, except for SD. The group containing FRS instructors and NATOPS checkers displayed higher confidence in future technology than those that did not. The other five technology variables exhibited no pattern at all.

Finally, a qualitative measure of technology responses revealed that from ranks O-2 to O-5, no significant trends existed.

Summary

The analysis from this chapter reveals some interesting findings. Generally, categories drawn along aircraft lines are strongest. Comparing pilots to NFOs also produces relevant results. The categorization by rank and combat time yield mixed results. And the experience level comparisons yield less usable data. While the graphs, tables, and explanations presented in this chapter are interesting, Chapter 5 will examine these results in more detail and provide possible recommendations for the future use of this data. The investigative questions concerning aircrew survivability, mission success, and the effect of technology on aircrew workload will be evaluated to shed some light on the research question.

Findings may indicate that technology improvements will be more pronounced in the lower threat missions of tomorrow; but for higher threat missions only slight improvements can be made. Because the perception is that technology may replace the NFO in the future, it is understandable that NFOs would minimize technology's affect. The overall perception of technology in the future is that it will tend to

reduce aircrew workload. The respondents do not seem to exhibit a great deal of confidence in their collective opinions, however, as responses are in the neutral portion of the response zone. It is interesting to note that combat veterans place less stock in technology improvements than do those without combat time. It is also interesting to note that the extreme ends of the current technology scale seem to exhibit the extreme ends of the sample data given. The F-18 pilots displayed the strongest support for the idea that technology can reduce workload while the A-6 community was noncommittal. These ideas will be discussed further in Chapter 5.

V. Conclusions

Introduction.

This chapter will build on the data and analysis in Chapter 4 to answer the investigative and research questions from Chapter 1. In order to accomplish this, explanations of both overall and categorical data are presented. As noted in Chapter 4, significant variances exist across certain categories. In varying degrees, all four of the independent variables, crew position (pilot or NFO), mission area, technology context (current or future), and type aircraft flown affect the dependent variables. The dependent variables again are mission survivability, mission success, and aircrew workload.

The differences noted in the dependent variable responses across both independent variables and key demographic categories vary from slight and not statistically significant, to extreme with a high degree of correlation. Individual aircrew comments are a helpful source in explaining differences along categorical lines. A complete list of these comments, along with the respondent's rank, type aircraft flown, and crew position can be found in Appendix D.

The objective of this chapter is to draw concise, objective conclusions that are fully supported by the data and analysis in Chapter 4. With the above objective in mind, Chapter 5 is organized in the following manner. First, an evaluation of the three investigative questions and accompanying hypotheses is presented. The evaluations of the investigative questions are then used to answer the research

question. Next, because this study was inspired by, and parallels in structure, the Starr and Welch USAF study, a qualitative comparison of the USAF and USN studies is made. Finally, the chapter concludes with recommendations and a brief summary.

Investigative Question One, Survivability

The investigative questions require answers concerning aircraft survivability, mission success, and the effect of future technology on aircrew workload.

The first investigative question is:

1. To what degree is survivability affected by crew complement?

Hypothesis: The presence of an NFO will not affect survivability.

At the 90% confidence interval used, the overall data supports an alternative hypothesis. Specifically, this alternative hypothesis is that the presence of an NFO does affect survivability. While the overall data supports the alternate hypothesis mentioned, a significant variance exists across the sample. The perceived degree to which survivability is affected by crew complement varies significantly by mission flown, type aircraft flown, and crew position. The measured difference between aircrew attitudes for one- and two-seat survivability is a direct measure of NFO contribution (or detraction) as it is affected by the three independent variables mentioned above. The technology context in which the aircrew responded (current or future) caused a slight and consistent variance. In general, aircrew members indicate more confidence for both one- and two-seat operations with

newer technology. Where necessary this variable will be specifically addressed. If not specifically addressed it can be assumed the conclusions drawn are valid in both the current and future context.

The most significant categorical variance exhibited in the data is in the area of type aircraft flown. Three of the four aircraft communities surveyed demonstrated the same general response pattern in a majority of categories analyzed. The A-6, F-14, and EA-6 communities (pilot and NFO) all indicated survivability to be less of a concern in the two-seat configuration. They indicated that this enhancement in survivability was true in both the current and future technology context. The fourth aircraft community, F/A-18 pilots, exhibited a response pattern that was essentially reversed from that of the other three aircraft communities. In all but the high threat interdiction (HT) and night/all weather interdiction (NT) missions, F/A-18 pilots indicated a statistically significant preference for one-seat operations. In the NT mission they indicated no statistical preference for one- or two-seat operations, while for high threat (HT) they slightly preferred one-seat operations. The F/A-18 responses indicate in all but the HT and NT missions the two-seat configuration is less survivable than the one-seat configuration.

The common denominator for the A-6, F-14, and EA-6 is that they are all multi-seat aircraft. The F/A-18 is a one-seat aircraft with a significant capability in all six mission areas surveyed. The trend to support the status quo with regard to crew complement is evident in all areas analyzed. The F/A-18 is the only one-seat aircraft the Navy flies

operationally. F/A-18 pilot responses, while representative in relative terms, make up approximately 20% of the overall sample base. Had the F/A-18 pilots been represented in more significant numbers, the overall evaluation of survivability with respect to crew size would have been different. The status quo bias will be addressed in more detail with an evaluation of other relevant findings.

Evaluation of relative differences between one- and two-seat capability across the six mission areas indicates a general concurrence among all four aircraft communities regarding relative NFO contribution by mission area. The measure of NFO contribution referred to is obtained by measuring the difference between one- and two-seat survivability in each mission area. These measures of NFO contribution are then ranked to allow comparison between mission areas. Table 8 provides a ranking of NFO contribution by mission area (top to bottom of the table) in order of increasing NFO contribution for survivability in the specific mission in question. Of note, HT and NT stand out as missions in which the addition of a crewmember could be most beneficial from a survivability standpoint. The F/A-18 pilots again indicate only slight (not statistically significant) preference for a one-seat configuration in the NT missions. The fact that the F/A-18 pilots do not indicate a significant preference for one- or two-seat operations in the NT mission suggests from a relative viewpoint the NT and possibly the HT missions are more suited to two-seat operations than are the other four missions. Due to a preference for one-seat operations, the

F/A-18 pilot data moves from "detracts most" to "detracts least" with regard to NFO contribution.

An exception to the NFO contribution ranking is the EA-6B pilot data. EA-6B pilots believe suppression of enemy air defenses (SD) to be the mission in which the NFO can contribute the most to survivability. Interestingly, EA-6B NFOs disagreed with their pilot counterparts and ranked NFO contributions in the SD mission as less important than in the HT and NT missions. It is worthwhile to again mention the potential problems associated with a one- and two-seat survey being filled out by aircrew flying a four-place aircraft. The capability of the four-place EA-6B is significantly different than that of other Navy SD capable aircraft. It is understandable that EA-6B aircrew would be pessimistic regarding the execution of their mission as they know it in either a one- or two-seat configuration.

Low threat interdiction (LT) and suppression of enemy air defenses (SD) typically rank as the missions where the NFO contributes relatively

TABLE 8

NAVY AIRCREWS RATE RELATIVE NFO CONTRIBUTION TO SURVIVABILITY BY MISSION
(RELATIVE CONTRIBUTIONS INCREASE FROM TOP TO BOTTOM AND LEFT TO RIGHT)

F-18 Plts	F-14 Plts	A-6 Plts	EA-6B Plts	F-14 NFOs	A-6 NFOs	EA-6B NFOs
AS	*SD	SD	AS	*SD	SD	*AS
*CA	*LT	LT	CA	*LT	*AS	*LT
*LT	+AS	*AS	HT	CA	*LT	*CA
+SD	+CA	*CA	*LT	AS	CA	SD
+HT	#HT	+HT	*NT	NT	HT	+HT
NT	#NT	+NT	SD	HT	NT	+NT

The symbols *,+,# indicate ties for relative contribution of the NFO.

the least to survivability. F-14 pilots indicated they were more survivable in a two-seat configuration for these mission areas. However, they acknowledged a capability to be survivable in a one-seat configuration. F-14 NFOs were not optimistic of survivability in a one-seat configuration. F-14 NFOs were, however, very optimistic of survivability in their current two-seat configuration.

Table 8 shows that pilots and NFOS as a whole exhibit little difference in how they rank NFO contribution by mission. The ranking by crew position parallels the overall (pilot and NFO) ranking of NFO contribution. There appears to be evidence to support two-seat operations for high threat and night/all weather interdiction missions. Even the F/A-18 pilots by their neutral stance indicate night interdiction to be significantly more difficult than the other missions in which the F/A-18 has a capability. It must be noted that in the five other mission areas the F/A-18 pilots indicate an additional crewmember detracted from survivability.

On the other hand, there appears to be a growing sentiment that the low threat and air superiority missions are survivable in a one-seat configuration. Support of one-seat operations in the LT and AS missions is even greater in the context of future technology.

Variances between aircrew with and without combat time are slight and not statistically significant in most mission areas. The overall trend for both pilots and NFOs with combat time is that they rate survivability higher for both one- and two-seat configurations than those without combat time. This higher rating was incrementally more

significant for two- than one-seat aircraft. In other words, those with combat experience rate the NFO's contribution to survivability higher than those without. A part of this optimism may be explained by the fact that the majority of these aircrew obtained this combat experience in Operation Desert Storm. Desert Storm proved to be a relatively permissive environment with air superiority obtained early in the war. The variances in this combat experience category are not significant enough to draw any further conclusions.

Experience as measured by flight time or rank had little effect on aircrew attitudes as a whole. Of note, one-seat missions were rated as more survivable as experience increased. This increased rating could mean the perceived NFO contribution to survivability decreases as experience increases. No trend at all was evident for two-seat operations.

It appears there is considerable disagreement regarding the relative contribution of an additional crewmember towards survivability in general. There is little doubt that more information can be processed in the two-seat cockpit. However, what is the crew coordination cost associated with this extra processing capability? Can an NFO aid in decision making or be a decision maker himself? Poor/delayed decisions due to problems with crew coordination must be acknowledged as a valid concern. From a survivability standpoint delayed decisions can be costly. On the other hand, poor decisions made in a task saturated environment can be equally costly. It is reasonable to assume that there are certain missions where important tasks can be

handled by an additional crewmember. Some electronic warfare functions come to mind as a good example. Another example is manual laser tracking for guided weapons. If technology in a particular mission area can provide all the information the pilot needs and therefore allow an informed decision making process, then an additional crewmember may in fact not be required.

From a survivability perspective, it appears that USN aircrew perceive low threat interdiction and close air support are missions in which technology can do the job. It further appears that technology is making significant gains in the air superiority mission. Analysis in the suppression of enemy air defenses is unfortunately clouded by the mission definition mentioned earlier. SD, as it is performed by the F/A-18 and A-6, seems to be another mission that technology is assisting in decreasing workload. This decreased workload allows survivable one-seat operations in the SD mission. SD, as it is performed by the EA-6B, however, is not considered feasible in a one-seat configuration. This low rating may reflect a concern by the EA-6B crews of high mission specific workload detracting from survivability.

In the high threat and night/all weather interdiction missions, the results of this study indicate that from a survivability standpoint an additional crewmember may still be required. Aircrew indicated these missions as the most complex and demanding environments in which they operate. There is no evidence to support replacement of a crewmember by technology in the NT and HT mission areas. Further, caution is indicated in how current aircraft are employed.

Investigative Question Two. Success

This section will look at the second mission effectiveness factor examined, mission success. Mission success is defined as the literal completion of the assigned mission. While success and survivability are closely related, this division intentionally allows analysis and evaluation of NFO contribution with respect to the complexity associated with accomplishing the mission itself.

Investigate question two asked:

To what degree is mission success affected by crew complement?

Hypothesis: The presence of an NFO will not affect mission success.

Much the same as for survivability, the overall data again supports an alternative hypothesis. This alternative hypothesis is that the NFO does affect mission success. As with survivability, this answer requires further explanation. Type aircraft flown affects the response of the aircrew significantly. A trend towards maintaining the status quo is again evident. Aircrew from multi-seat aircraft weigh NFO contribution more heavily than do one-seat pilots. Attitudes regarding mission success are also significantly affected by mission area flown and crew position. Flight experience, rank, special qualifications held, and combat time all had minimal effect on the overall trends. Additionally, the technology context (current or future) affected the results in a slight and consistent manner. Unless otherwise noted, any evaluation can be assumed to be valid in either the current or future context.

The largest variance by category is in a division of aircrew by type aircraft flown. The multi-seat aircraft aircrews all rated NFO contribution high. This high rating is particularly evident in their respective primary mission areas. A detailed evaluation of the relative mission area ratings for NFO contribution will be discussed later. F/A-18 pilots indicated in all but the HT and NT mission areas for current data, and only NT for future operations, that the NFO detracted from mission success. In the HT and NT mission the NFO was rated to have had no effect on mission success. One- and two-seat capabilities were statistically equal. Of note, the only category in which the F/A-18 mean response was better for a two-seat configuration was for current technology in the night interdiction mission. Again, this preference was not statistically significant at the 90% confidence level. The A-6, F-14, and EA-6B aircrews all rated two-seat performance higher for all six missions.

A preference for maintaining the status quo with respect to crew complement is indicated. This preference again meant the F/A-18 responses were numerically dampened by the other three aircraft communities. If a greater number of one-seat pilots had been represented, the results would have been significantly different. Again this does not prevent a determination of NFO contribution by mission area. Table 9 is similar to Table 8 presented in the previous section and displays the same results for mission success. HT and NT are again rated by all but the EA-6B pilots as missions in which an NFO can

contribute most. LT, CA, and SD again are ranked as areas where the NFO contribution is relatively less vital.

TABLE 9

NAVY AIRCREWS RATE RELATIVE NFO CONTRIBUTION TO SUCCESS BY MISSION (RELATIVE CONTRIBUTIONS INCREASE FROM TOP TO BOTTOM AND LEFT TO RIGHT)

F-18 Plts	F-14 Plts	EA-6B Plts	F-14 NFOs	A-6 PLTS	EA-6B NFOs	A-6 NFOs
AS	LT	AS	LT	SD	*LT	SD
*CA	SD	CA	*SD	AS	*CA	AS
*LT	AS	HT	*CA	LT	AS	LT
*SD	CA	LT	AS	CA	+SD	CA
HT	NT	+SD	HT	HT	+HT	HT
NT	HT	+NT	NT	NT	NT	NT

The symbols * and + indicate ties for relative contribution of the NFO.

The F/A-18 pilots are again an exception in that they rank NFO contribution as a detractor in all but HT and NT missions (only NT in a future context) . The F/A-18 data moves from "detracts most" to "detracts least" with regard to NFO contribution. As mentioned, EA-6B pilots believed SD was the most important (this time tied with NT) mission from an NFO contribution perspective.

F-14 pilots and NFOs rated their own primary mission area (AS) behind both HT and NT from a success perspective. In other words, they believed an NFO could contribute more to success in the HT and NT missions than in the AS mission.

Categorizing by pilot and NFO shows little difference with respect to degree of NFO contribution by mission area. Pilots rate the NFO

contribution to mission success in the air superiority mission lower than do NFOs. This lower rating is consistent with the trend noted in survivability. Looking at the overall data, CA, SD, and AS were comparably rated as the lowest level of NFO contribution.

All multi-seat aircraft rated NFO contribution greater for success than for survivability. F/A-18 pilots gave only slightly more credibility to NFO contribution with respect to mission success than survivability. The perception of an NFO contributing more to success than to survivability is consistent with a number of the comments reported. An O-5 A-6 pilot states, "Unless technology greatly eases crew loading in a high tempo/high threat scenario, dual-seat will always be more successful in mission completion. Survivability is not as seriously affected by dual-seat as is mission completion." This issue of relative importance will be addressed in more detail later in the chapter.

As when considering survivability, combat time had little affect on the results. Aircrew members with combat time tended to be slightly more optimistic about mission success for both a one- and two-seat configurations than those without combat time. This optimism, however, was not statistically significant at the 90% confidence level. There is a greater emphasis on NFO contribution with respect to mission success for those with combat experience. In other words, combat experienced aircrew members were more optimistic towards mission success in general. They indicated a higher incremental increase in success rates for two-seat operations relative to one-seat operations. Experience, as

measured by rank or flight time, played no significant role in the evaluation of mission success. As with survivability, one-seat operations were rated as slightly more successful as experienced increased. The results were not significant enough to draw any conclusions.

Like survivability, aircrew members have differing opinions regarding the contributions of an additional crewmember to mission success. The same reasons cited in the context of survivability are valid for success. The F/A-18 aircrew members once again indicate that they can do it as well or better in a one-seat configuration. The "as well" part is again in the NT and HT missions. Multi-seat aircrews in general respond in a manner that preserves the status quo.

An exception is in the area of air superiority. There is evidence to suggest that the AS mission, in all but the most demanding circumstances, is capable of being executed by a one-seat aircraft. The F-14 aircrew members, both pilot and NFO, indicate NFO contribution is relatively less important when compared to the HT and NT missions. From the specific comments received by F-14 aircrew, it is evident that a number of those who do support an NFO do so on the basis of multi-role employment. An O-3, F-14 NFO states, "With multi-mission aircraft being the platform du jour, it makes sense to have two people in these aircraft." This concept of multi-mission tasking will be addressed in more detail later in the chapter.

The low threat interdiction and close air support missions are generally indicated to be successful in a one-seat configuration. In

the SD mission the results are again somewhat clouded by two definitions of the mission itself. The EA-6 aircrew responses indicate that the SD mission, as they know it, is definitely better performed from a mission success perspective in a two-seat (or more) configuration. Crews from the other two SD capable aircraft (F/A-18 and A-6) rate this mission as less demanding and relatively less vital from an NFO contribution perspective. It is likely that the SEAD mission the F/A-18 and A-6 currently perform is made possible with technology. With the increased mission scope of the EA-6B, additional crewmembers are still needed.

As with survivability, high threat interdiction and night/all weather attack both still seem to indicate the need for an NFO. The F/A-18 aircrews do not directly validate this need. However, as with A-6 aircrew not fully appreciating one-seat operations, a majority of F/A-18 pilots have no operational two-seat experience. A number of comments from pilots and NFOs alike flying all four types of aircraft indicated the HT and NT missions to be the most demanding. Recent experiences with the F/A-18 and the F-16 in Operation Desert Storm have demonstrated one-seat capabilities. This same experience has also clearly indicated the difficulty associated with night/all-weather interdiction in a one-seat aircraft. It appears that as with survivability, technology does not yet allow a one-seat aircraft to be effective from a mission success perspective in the NT and HT missions. The same cautions regarding design and employment of aircraft applicable to the discussion of survivability are valid for success. Caution must be taken to avoid tasking an aircraft to perform a mission in which it

has a relatively limited capability. If operations are deemed necessary in these particular environments, then the platform best suited to the job must be available and employed. This conclusion alone warrants at least a limited number of two-seat platforms be acquired.

Investigative Question Three, Technology

This section will provide the aircrew members' view of the effect of technology on aircrew workload in a similar manner as the previous two sections did for survivability and success. The six specific questions measuring aircrew attitudes in this area are asked on the survey in as unbiased a manner as possible. No specific examples of current or future technologies were provided to assist the respondents in their answers. All perceptions about technology were left to the respondent to decide. The investigative question is:

To what degree will technology affect overall aircrew workload?

Hypothesis: Technology will serve to increase overall aircrew workload.

In general, overall aircrew opinions supported an alternate hypothesis. This alternate hypothesis is that technology will serve to decrease overall aircrew workload in most mission areas. Analysis of the data, however, indicates less than complete support for this decrease in workload. An inspection of the confidence intervals presented in Figures 55 - 64 from Chapter 4 show most categories on the agree side of neutral. However, the proximity of the intervals to the neutral position indicates relatively weak support. According to the

data, the overall population expects a more significant workload decrease in the LT and SD missions than in any of the other mission areas. The evaluation of investigative questions one and two is consistent with this finding. Because these two missionc are viewed as the two most permissive environments, it can be concluded that any technology contributions would only serve to make the environments even more permissive.

Categorical analysis by aircraft type and crew position also reveals exceptions to the overall trend. F/A-18 pilots expect significant workload reductions in comparison to the overall group as a result of advanced technologies. Because their aircraft is the most advanced of all aircraft in the population, it is reasonable to assume that they have been exposed to more advancements than aircrew flying other aircraft. F/A-18 pilot optimism must be weighed heavily regarding technlogy's benefit given their exposure to the newer technology. In contrast to F/A-18 pilots, two groups (A-6 NFOs and F-14 NFOs) are of the opinion that technology will not affect workload one way or the other. Both the F-14 and the A-6 aircraft possess relatively older technology than the F/A-18 and, as such, have not been exposed to many of the newer advances. The fact that they have not been exposed to the same technology the F/A-18 crews may contribute to their attitude. While numerous upgrades have been made to both the F-14 and A-6, these upgrades all are technology workarounds. Specifically, the newer technology has been incorporated as it became available into the overall system design. Improvements of this nature are not ideal with respect

to aircrew workload. These upgrades are likely responsible for a part of the F-14 and A-6 aircrews attitudes. It must also be acknowledged that because NFOs rated technology's contribution to workload reduction lower than did pilots, a degree of role preservation/job protection may enter into the attitudes presented. Recent trends to increase the number of F/A-18s and decrease the number of F-14s and A-6s on aircraft carriers make this a timely and critical question to these NFOs.

Of the remaining categories, the EA-6B NFOs interestingly do not stand out one way or another from the overall group. Based on previous data, one would expect the EA-6B NFOs to view technology as a potential threat to them as well. One explanation to support their lack of dissent is that the EA-6B is the only dedicated SD asset in the Navy. Current plans include the EA-6B as a significant factor for carrier operations well into the future. The aircraft is still in production and, consequently, any threat to the EA-6B NFO position is well in the future. Further, the EA-6B, from an avionics standpoint, contains relatively new technology and the aircrew view this technology as a positive force.

The remaining three groups (F-14 pilots, A-6 pilots, and EA-6 pilots) all show moderate agreement that technology will decrease overall aircrew workload. Of the three, F-14 pilots expect the largest reduction in workload, and EA-6B pilots expect the smallest reduction in workload. Consistent with the overall data, categorical analysis supports the trend that SD and LT missions should exhibit more workload reduction due to technology than other missions.

When categorized by pilot and NFO, the SD and LT trends mentioned above continue. A noteworthy finding in this categorization is that pilots tend to perceive technology as a workload-reducer and NFOs view technology as workload-neutral. The best explanation for these differing viewpoints is that pilots may view technology in terms of systems designed to enhance their mission effectiveness. NFOs, on the other hand, probably view any new systems as another piece of equipment that requires their attention. Once again, technology may be viewed as a threat to existence of the NFO as opposed to the view that technology should supplement the NFO role. Some indicate that technology should be there to complement the existing crew and not reduce it. An O-3 A-6 pilot with previous NFO experience said, "It is getting easier with new generation aircraft to overload a single person. The more info he is faced with, the more 'spills out the bucket.'" The fundamental argument to justify the NFO position then becomes: better technology means more information, and more information means more distractions. Hence, someone other than the pilot, whose primary mission is to fly the aircraft, must be there to handle the "spillage." This explanation seems to be further supported when the data is sorted along combat/non-combat lines.

Aircrew with combat time view technology's ability to decrease workload differently than those without combat time. Combat experienced aircrew are less optimistic in their opinion that technology will decrease workload in all but the LT and SD missions. In the LT and SD missions they give technology a slight capability with respect to

workload reduction. These aircrew have witnessed first hand what a dynamic environment combat can be. Though they tend to agree overall (very slightly) that technology should be helpful and reduce workload, their confidence for this position is weak. Aircrew without combat experience tend to place more confidence in technology's ability to reduce workload. This result in a sense is in opposition to the relative optimism regarding overall capability of the combat experienced aircrew reported earlier. A possible explanation is the common shared experience, Operation Desert Storm. The experienced aircrew are confident of their ability to get the job done and return to base. Aircrew members, however, seem to acknowledge that in a threat scenario as permissive as Desert Storm combat is still a demanding environment.

The last categorization made is the experience level of aircrew for determining the relationship between technology and workload. Though one would expect some differentiation along these lines, no significant trends were noticed. All ranks (O-2 through O-5) tended to expect greater workload reductions in SD and LT than the other missions. The only noticeable deviation was that O-3s and O-4s seemed to expect greater workload reductions in the LT and SD missions than their junior and senior counterparts. These results appear to be insignificant, but the difference exists nonetheless.

With regard to technology's affect on workload, three points seem to stand out. First, one-seat pilots tend to view advances in technology as more advantageous than two-seat crew members. Second, pilots think technology will help reduce overall workload, while NFOs

think technology will have little to no effect on workload. Finally, crew members with combat experience take a relatively neutral stance on the issue while aircrew who have not experienced combat seem to expect workload reductions in the future. The general attitude is that technology will increase overall capabilities in the future and reduce workload for specific tasks. But technology may also increase the number of tasks performed. This position is illustrated by an O-4 A-6 pilot. He states,

> Advances in technology seem only to increase the overall workload that is expected of aircrew. New missions, more options, increased weapons complexity, increased capability of IADS, increased airwing integration and additional joint operations require that today's or tomorrow's aviator use technology to decrease specific task workloads and effectively utilize task management in our favor to prevent aircrew overload.

His position indicates a confidence that technology can decrease task specific workload but that overall mission complexity and therefore overall workload is increasing. It is apparent that aircrew believe technlogy can and will increase capability. It is equally apparent that there is some concern over the role technology will play in the cockpit. F/A-18 pilots indicate that technology has made great strides in reducing workload and will continue to do so. Others seem to believe that technology would be more properly focused on enhancing current capability and less attention should be paid to crew complement reductions. It is fair to say that if technology does allow one-seat operations, then two-seat operations are inefficient. However, as mentioned in the two previous sections on survivability and mission success, if technology does not allow a particular capability one-seat

and that capability is required, then either a different platform must be employed (two-seat, cruise missile) or other means must be found to accomplish the mission.

Research Question

The research question of this study is: Do USN aircrews believe new cockpit technology can replace the need for Naval Flight Officers in future USN combat aircraft? The investigative questions and survey are designed to provide a framework from which to answer this question. The first two questions directly measure pilot and NFO attitudes regarding NFO contribution. In the two survey sections supporting these two questions pilots and NFOs assess the capability of both one- and two-seat operations in six critical mission areas. The third distinct segment of the survey measured the third investigative question. How is cockpit workload affected by technology? This question was asked in the context of the "latest technology" available. This technology-workload question checks the validity of the responses in the previous two sections.

The answer to the research question appears to be yes and no. The perceived feasibility of replacing the NFO is directly dependent on the specific mission in question. While the actual research question is broad in nature, the survey was designed to detect this variance by mission area. Any attempt at a generalization made across all typical combat missions regarding crew complement would be highly imprecise.

Before evaluating the results in the six individual mission areas, it is important to address multi-mission aircraft.

There is a trend towards design and employment of more capable multi-mission combat aircraft. Aircraft such as the F/A-18, F-16, and the F-15E are examples of aircraft with this multi-mission capability. Despite this added capability, there still is a distinct division of labor in our combat aircraft and the roles in which they are employed. As discussed in Chapter 3, this study intentionally did not ask the aircrew to assess multi-mission employment. By focusing on the six missions individually, a mission-specific data base was formulated. From this manageable data base, conclusions can be drawn not only in each specific mission but for a combination of missions.

Technology present in the F/A-18 Hornet now affords the Navy a significant capability in a number of critical missions. A convenient starting point is to examine two missions which the F/A-18 and its predecessor, the A-7, have successfully accomplished for years. Specifically, these two missions are low/medium threat interdiction (LT) and close air support (CA). The F/A-18 pilot data indicates these missions are better suited to one-seat operations. In both the current and future context of technology F/A-18 pilot results indicate an NFO actually detracts from mission effectiveness in these areas. As addressed in previous chapters, there are legitimate concerns regarding difficulties associated with crew coordination and decision making in a multi-place aircraft. The concern over these difficulties is reflected in the F/A-18 responses. Beyond the crew coordination and decision

making dilemma, it is also likely that a fair degree of role preservation and status quo bias is reflected in the F/A-18 data. The issue of NFO contribution versus NFO detraction will be discussed in more detail later in this chapter. It is important to note at this point that the decision point is not really a function of whether a two-seat configuration is better or worse, but whether one-seat is enough.

F-14 pilots and NFOs indicated that the LT and CA missions would be executable in either configuration. The F-14 aircrews did prefer two-seat operations, but they gave a significant capability to the one-seat configuration. Interestingly, the A-6 pilots and NFOs were less optimistic than the F-14 aircrew regarding one-seat operations in the LT and CA missions. This difference is easy to explain in the context of current capability. The A-6 in its current state would likely not be effective in a one-seat configuration. However, it is harder to explain why in the future section (latest technology and optimal design to execute the mission in question), A-6 pilots and NFOs still indicated a neutral to slightly negative response for one-seat capability in LT and CA.

It is generally accepted that the F/A-18 is a capable platform in these two mission areas. Both the U.S. Navy and the Air Force have used one-seat aircraft in these roles successfully since World War II. It is likely that a combination of a lack of knowledge regarding one-seat capability and a degree of status quo bias affects the A-6 results. A-6 crews perform all missions with two crewmembers integrated fully into the mission as the A-6 was designed from the ground up as a two-seat

aircraft. It is likely difficult for A-6 pilots and NFOs to completely assess one-seat operations given technology they do not have. Further, they too may be biased toward the current configuration in which they fly.

There is strong evidence to support one-seat operations in the LT and CA missions. The F/A-18 aircrew have considerable experience in these two missions and indicate no need for an additional crewmember to be either successful or survivable. Whether F/A-18 aircrews indicate the NFO would detract from the mission is irrelevant. If one crewmember can do the job, why use two? As further evidence, the A-6 aircrews indicate that an NFO is significantly less critical in these missions when compared to high threat interdiction (HT) and night/all weather interdiction (NT).

For the suppression of enemy air defenses (SD) mission, two separate and distinct attitudes are evident. Of the three platforms that perform this mission, the EA-6B is the most capable. Due to having SD as a dedicated mission and having considerable resources at hand to perform it, the EA-6B aircrews have a different view of what SD actually is. Advanced active and passive EW capability is an area in which confusion can arise when comparing the EA-6B to the F/A-18 or A-6. For the SD mission the EA-6B performs, the data indicates that more than one person is required. Alternatively, there appears to be evidence to support the SD mission the A-6 and F/A-18 fly in a one-seat configuration.

F/A-18 pilots expressed confidence in both the current and future context that they could effectively execute the SD mission. A-6 aircrews, while somewhat neutral regarding one-seat capability in the current context, expressed confidence in future technology's ability to make this a one-seat mission.

In the question that directly measured technology and its impact on workload SD was rated as a mission where technology could do the most. The overall data and a majority of the categorical data further indicate that along with LT, the SD mission was being made less difficult with new technologies. The conclusion to be drawn in the SD mission appears to center on the definition of the mission itself. Obviously a one-seat aircraft could not accomplish the SD mission the EA-6B performs. There is also a need, however, for the SD capability the F/A-18 and A-6 possess. It appears that technology will allow this F/A-18 and A-6 version of SD to be executed in a one-seat configuration.

A mission where there is less agreement regarding level of difficulty in the context of technology is that of air superiority (AS). A considerable variance is demonstrated by type aircraft flown and crew position. F/A-18 pilots rated air superiority as the least difficult mission to perform in both mission effectiveness categories. F-14 pilots and NFOs indicated that AS was the third most difficult mission behind HT and NT. A-6 and EA-6B aircrew rated AS in the bottom third in both success and survivability. The aircrew attitudes and background data addressed in Chapters 1 and 2 seem to indicate one-seat operations can be effective in the air superiority mission.

Technology in this area has improved drastically in the 20 plus years since Vietnam. Improved radar, weapons, and automatic cockpit functions all make this mission more and more achievable in a one-seat configuration. A number of comments received from F-14 aircrew support this claim. A top gun instructor NFO states: "Most air superiority missions in a 2 vs UNK (unknown) environment can be performed very effectively in a single-seat aircraft." This attitude is often caveated by comments concerning multi-mission tasking. For example, in an interdiction role with an air to air threat, the mission complexity and resulting workload is certain to increase. As mentioned previously, the aircrew were not asked to assess multi-mission tasking in the survey. This concern will surface again in the area of high threat and night/all weather interdiction (HT and NT) and will be addressed later in more detail.

In the HT and NT missions there appears to be a consensus that mission complexity and resulting workload are not as manageable in a one-seat configuration. Pilots and NFOs alike from all three aircraft with a capability in these missions rank HT and NT as the two most difficult missions. This ranking is true for both success and survivability. The results are split regarding which is more difficult (HT or NT) from a survivability standpoint. From a mission success standpoint, however, pilots and NFOs in all three aircraft rank NT as more difficult. These are the only two missions where the F/A-18 pilots did not indicate that NFOs detract from the mission. At the 90% confidence level, no significant difference in F/A-18 pilot assessment

of one- and two-seat capability is noted in either mission for either effectiveness category. F-14 and A-6 aircrews (pilots and NFOs) indicated a significant improvement in capability by adding an NFO for both success and survivability in a two seat configuration. In fact, F-14 and A-6 aircrew responses satisfied a 99% level of confidence.

The data strongly indicates the HT and NT mission to be the two most complex and demanding out of the six missions addressed. It is apparent that there is little confidence that technology can supplant the role of the NFO in these mission areas. In the direct question measuring technology versus workload, this conclusion was validated. These two missions were ranked as the areas in which technology was making the slowest gains. Workload in the context of new technology was still rated as decreasing but at a slower pace than that of the other six mission areas. Improvements such as night vision and infrared technologies are positively affecting our ability to operate at night. While these technologies and similar technologies are making gains, the data suggests that these missions are still complex, high workload environments where two crewmembers are required.

One can not totally discount as biased the F/A-18 neutral stance towards one- and two-seat capability in these two mission areas. Literally interpreted, the F/A-18 results indicate no benefit to adding an additional crew member. The F/A-18 is an extremely capable aircraft with a demonstrated role in night interdiction. This F/A-18 capability in night and high threat interdiction must be objectively assessed alongside capabilities of aircraft like the A-6, F-111, and the F-15E.

Is the F/A-18 as capable? Is it capable enough? While the A-6 and the F-111 are aging platforms that themselves are in need of replacement, the capability of the F-15E is undeniable. A number of individual survey comments were received that indicated the F/A-18 did not perform as well as the A-6 in a recent operational employment (Operation Southern Watch). If the individual services decide they require an aircraft with the capability to perform missions that the A-6, F-111, and F-15E are capable of performing, it is apparent that two seats are required. Any one-seat capability at present and in the near future will represent a compromise in this capability.

This section has focused on each specific mission individually. Multi-mission demands are again acknowledged as playing a significant role in any decision made regarding design or employment of combat aircraft. Multi-mission demands will be addressed in more detail in the chapter summary and study recommendations.

USAF and USN Study Comparison

The study of USAF pilots conducted by Starr and Welch has been referred to throughout this study. The USAF study differed slightly in structure from this USN effort. The studies, however, shared a similar research question. The USAF study research question was, "Do pilots believe the NAV/WSO/EWO can be effectively replaced by new cockpit automation technologies on aircraft performing in high threat combat environments?" (Starr and Welch, 1991:1-10). To answer this research question the USAF study asked four investigative questions. The first

question measured USAF beliefs regarding critical mission effectiveness factors. Specifically, the pilots were asked to provide and rank in order of importance the factors critical to being effective in their respective mission.

The second investigative question measured whether a NAV/WSO/EWO would enhance performance. This performance measure was conducted categorically by type aircraft. The third question focused on the entire mission itself. Given the entire mission focus the pilots were asked to evaluate the need for a NAV/WSO/EWO. The fourth investigative question checked to see whether a pilot's individual experience level had an effect on the data.

The USAF study measured only pilot attitudes. It covered a majority of the fixed wing aircraft the USAF operates. This broad coverage enables comparison with similar platforms the U.S. Navy operates. A quantitative comparison will not be made. It is more useful to examine specific trends along the shared focus of the respective studies.

The USAF data in general paralleled the USN data. The aircrew who currently fly multi-seat aircraft were more supportive of that configuration. The one-seat pilots tended to support operations in a one-seat configuration. Aircrew from aircraft such as the B-52 and F-15E tended to respond in the same manner as the A-6E, EA-6B, and F-14 aircrew. USAF F-16 and A-10 pilots demonstrated similar attitudes in responding as the USN F/A-18 pilots.

The USAF study also indicated USAF pilots had confidence in technology and its impact on cockpit workload. The USAF pilots in general felt that technology would in fact decrease workload. The one-seat pilots indicated that in less demanding missions this decrease in workload served to make one-seat operations even more effective. USN F/A-18 pilots indicated a similar attitude towards technology and its affect on mission effectiveness. In four of the six missions surveyed (all but HT and NT), F/A-18 pilots indicated that an NFO would detract from mission effectiveness. In the HT and NT missions F/A-18 pilots indicated that the NFO would not have either a positive or negative impact on mission effectiveness. A number of F/A-18 comments indicated these missions, specifically the NT mission, to be areas where in fact they had a limited capability relative to other mission areas. This attitude was present in the USAF F-16 pilots as well. The F-16 is capable of flying the night mission utilizing a low altitude navigation and targeting infra red night pod (LANTIRN). A number of the comments by USAF F-16 pilots with experience in this mission indicated that it may be better suited to a two-seat aircraft. This grudging admission, present in both the F-16 and F/A-18 pilots, supports both studies' conclusions that for these high workload/high complexity missions technology does not support one-seat operations.

Multi-seat USAF aircrews indicated that while technology in fact decreased workload, that the addition of technology served to "enhance the performance of the NAV/WSO/EWO" (Starr and Welch,1991:5-35). This same attitude was evident in the USN responses survey data and comments

as well. USN crews who currently flew a two-seat aircraft generally believed that there were definite advantages to having an extra crewmember. An exception was the F-14 pilots and NFOs in the air superiority mission. As mentioned earlier there was evidence to support one-seat operations in the AS mission. F-14 aircrews were more optimistic in their current two-seat configuration but gave a significant capability to one-seat operations given next generation technology. Air superiority has been the primary mission of the F-14. Interestingly, the F-14 pilots and NFOs indicated that the HT and NT missions were not areas where technology would allow one-seat operations. Further, a number of the F-14 comments pointed to the valid point that all missions are potentially multi-mission in nature. Noticeably missing from the USAF study was the inclusion of an AS dedicated aircraft. F-15s were still deployed to the Persian Gulf at the time and their pilots were unavailable for comment. No direct comparisons between the F-14 and F-15 can be made.

Summary and Recommendations

This research has addressed only a small part of a larger issue. Resource constraints unfortunately did not allow exploration of all pertinent and related issues. While a number of specific studies have been conducted on the one- and two-seat issue, there is a conspicuous lack of recent data to support this issue. This study provides important information from a typically untapped source, the operators. What do today's pilots and NFOs think about the crew complement issue?

There is overwhelming evidence to suggest that there is more to this issue than adding multi-function displays, automatic radar locks, and updated navigation equipment.

Technology has proven itself to be a two-edged sword. The very technology that provides added capability may, in some cases, come at the expense of increased complexity. Consider multi-mission aircraft. To this point, multi-mission aircraft have only been addressed in an introductory fashion. The added difficulty this multi-role concept adds to the assessment of the one- and two-seat issue is important. This research has intentionally focused on identifying the aircrews' attitudes regarding crew complement in six specific mission areas. These mission areas were each addressed individually and no attempt was made to combine one with another. There is significant data to suggest that single mission tactical aircraft are not efficient force multipliers. The recent move to establish an air-to-ground capability for the F-14 is concrete evidence of this attitude. Austere funding is an unfortunate reality for the U.S. military. In light of this funding, multi-role aircraft are likely to receive even more attention. Multi-mission capability serves to make the cockpit workload more complex. This added complexity must be a consideration in both design and employment. The senior leadership in the military is in the unenviable position of attempting to field capable systems in significant numbers despite limited funding. Finding a balance between capability and numbers will not be easy. The rate at which military aircraft costs have increased only exacerbates this problem. This research

conclusively demonstrates that USN aircrew members perceive in a number of mission areas that mission effectiveness is increased significantly by having an additional crewmember on board. The previous USAF study came to the same conclusion. These indications of increases in mission effectiveness gained by having an additional crewmember cannot be ignored. Many point to the F-117 and its performance in Operation Desert Storm as evidence of technology's ability to allow complex one-seat operations. The effectiveness of the F-117 in its intended mission is undeniable. Its inflexibility in comparison with a platform such as the F-15E is equally undeniable. If we were to not have platforms such as the F-15E and the A-6, would we be able to search out and destroy mobile targets at night or in bad weather?
Is this a capability we can afford to sacrifice? This is but one example of the difficult decisions facing our planners and senior leadership.

While this research did demonstrate that the aircrew in general have confidence in technology and its impact on workload, there was only a slight improvement in perceived capability indicated between today's and tomorrow's systems (current and future context of technology). This conservative optimism must be considered when placing emphasis on technology in future aircraft. It may be unwise to make assumptions regarding increased future capability when there is evidence to suggest our aircrews are, in some cases, overloaded in today's aircraft. It is a certainty that in some mission areas, technology can and will do the job. While a certain amount of subjectivity and personal opinion is

present in any undertaking such as this, great pains have been taken to focus on objectivity. It was not the intention of this study to provide the entire answer and a matrix of crew requirements by mission and combinations of missions. Hopefully, at a minimum, the reader will agree there is cause for caution before commiting to wholesale design and employment changes in our combat aircraft. Capability of current and future systems must be accurately and objectively assessed. A number of comments received point to Operation Southern Watch as a timely example of an inaccurate assessment of capability. Aircraft such as the F/A-18 Hornet are, and should be, the mainstay of the Navy's air arm. It is arguably the most capable aircraft in the world. While the number of situations it can be employed in are considerable, its limitations must also be accurately assessed. If mission requirements exist in areas where the F/A-18 is deficient, then aircraft must be available to execute these missions.

Attitudes can reveal a great deal of information, but cannot establish the type of results necessary to determine technical performance levels. A way to more scientifically answer this study's research question is to test well-trained aircrews (both one-seat and two-seat) in a wide variety of missions. Studies regarding the issue of crew complement conducted with aircrews in combat training exercises or realistic simulations would be invaluable. An example of such a study would be to perform a detailed analysis of the Fallon Weapons Detachment, Top Gun, Red Flag, or Maple Flag exercises. Another method for conducting a study would be to devise a simulation scenario. The

scenario should compare one-seat pilots' performance to two-seat formed crews. To be a valid comparison, the scenarios should be designed to simulate combat conditions. The cockpits used should be optimal designs for both one- and two-seat configurations.

Along with these studies, a move to decide the crew complement issue in the demonstration and validation phase of a particular aircraft acquisition program would likely be an effective way of ensuring specified performance. No doubt, political and cost considerations would be a factor but at least more could be learned regarding the capabilities of either configuration.

A suggestion that may be within the scope of another thesis effort would be to examine how crew complement decisions have been made in past programs. Such an analysis would possibly end a good deal of the speculation associated with how these decisions are made. Further, it would provide insight as to how improvements can be made to the process.

Appendix A: Sample Survey Request and Approval Letter

Appendix (A) contains the survey approval request the U.S. Navy requires prior to surveying USN personnel. The specific information requested and enclosures provided are listed on the formal request cover letter. This appendix also contains the approval letter received from the Bureau of Naval Personnel authorizing the survey.

30 April 93

From: LT William J. Cain USN/CAPT Robert E. Britt USAF
To: Chief of Naval Personnel (Pers-01JJ)
Via: Headquarters Naval Air Systems Command (Air 531-C)

Subj: REQUEST FOR APPROVAL OF NAVY PERSONNEL SURVEY

Ref: (a) OPNAVINST 5300.8B

Encl: (1) OPNAV 5214/10 Report Analysis Data
(2) Final Draft Combat Aircrew Survey
(3) Dean, Air Force Institute of Technology ltr
(4) Computer-readable Survey Item and Content Summary
(5) Headquarters Naval Air Systems Command ltr

1. Per reference (a), request approval to conduct a personnel survey of Navy combat aircrews attached to non-deployed active airwings.

a. Purpose. A key design point in the development of modern combat aircraft is crew complement. Only a modest amount of specific data regarding this issue exists. A survey and follow-on statistical analysis of USAF aircrew attitudes conducted in 1991 provided a valuable insight into the issue. The survey of USN aircrews will provide the same insight for the Navy and be of potential use in the development of our next generation combat aircraft.

b. Justification. A specific aim of this study is to assess aircrew inputs towards crew complement requirements in typical combat scenarios. In order to realize this goal, direct aircrew inputs are required. Due to the geographic dispersion of the respondents, a written survey is the most cost effect means for gathering the data. Enclosure (1) estimates the cost to complete this survey at a one time cost of $15,691.29. This cost is justified given the critical importance of ensuring correct decisions are made in this issue.

c. Participation. In order to obtain the desired degree of significance, all non-deployed active airwings will be targeted. Specifically, the F-14, F/A-18, A-6, and EA-6B aircrews will be asked to respond. Emphasis will be placed on the need for experienced inputs hopefully resulting in a stratified random sample. With approximately 92 aircrew (pilot and Naval flight officer) in these four aircraft, and an anticipated 50% response rate, this should yield 380 responses from eight different Airwings. Liaison with two of the eight Airwings to be surveyed indicates they are not overwhelmed with requests of this nature and are willing to participate.

Subj: REQUEST FOR APPROVAL OF NAVY PERSONNEL SURVEY

d. Technical Development. This one time survey will be administered and analyzed by the research team with assistance and guidance from faculty advisors. Both members of the research team (LT Cain and CAPT Britt) are graduate students in the systems management program at the Air Force Institute of Technology (AFIT). The faculty advisors are Dr. David Kirk Vaughan and Dr. Guy S. Shane. Dr Vaughan is a retired Air Force pilot with 20 years of service. He has a PhD in English from the University of Washington and has taught at both the undergraduate and graduate levels. Dr Vaughan is an Assistant Professor of Technical Communication and has been at AFIT for six years. Dr. Shane has a PhD in Industrial-Organizational Psychology from George Washington University with more than 25 years experience in personnel selection and employee attitude research. He is an expert in test and survey development. Dr Shane is an Associate Professor of Management and Organizational Behavior and has been at AFIT for 12 years. The survey is in the process of being pretested locally and any required amendments will be specifically cleared through PERS 01JJ.

e. Analyses. The research team with assistance from faculty advisors will use accepted statistical techniques and the SAS statistical software to analyze data. A five-point Likert scale is used to measure the responses in a variety of scenarios. Demographics contains nominal data and will not be scored. The results of this survey will be compared with the results of the USAF survey and further analyzed. Once analysis is complete the data will be provided to current development programs within the Navy and Air Force in addition to being made available through the Defense Technical Information Center (DTIC).

f. Life Cycle. This is not a recurring survey. It will expire on 30 September 93.

g. Sponsor Point of Contact. Naval Air Systems Command POC is Mr. Howard Arnoff (Air 531-C). He can be reached at (703) 692-7486/DSN 222-7486.

2. POC for this request is LT William Cain. (513) 236-5012

WJ Cain

WILLIAM J. CAIN, Lieutenant, USN

Robert E Britt Jr.

ROBERT E. BRITT, JR., Captain, USAF

REPORT ANALYSIS DATA

1. SSIC NUMBER	2. REPORT CONTROL SYMBOL

3. TITLE OF REPORT
COMBAT CREW REQUIREMENTS (AIRCREW PERSONNEL SURVEY)

4. PURPOSE OF REPORT
TO GATHER DATA FROM USN COMBAT AIRCREWS REGARDING CREW COMPLEMENT ISSUES.

5. REQUIRING DIRECTIVE(S) *(List all that apply)*
NA

6. FREQUENCY OF REPORT
☐ DAILY ☐ QUARTERLY ☒ ONE TIME
☐ WEEKLY ☐ SEMI-ANNUALLY ☐ SITUATIONAL
☐ MONTHLY ☐ ANNUALLY ☐ ________

7. REPORT FORMAT
☐ MESSAGE ☒ LETTER ☐ FORM *(Attach copy)*

8. IS REPORT SUBJECT TO MINIMIZE?
☐ YES ☐ NO ☒ NOT APPLICABLE

9. METHOD OF PREPARATION
☐ ADPE ☐ TYPEWRITER ☒ MANUAL ☐ ________

10. IS REPORT ENTERED INTO AN ADP SYSTEM?
☒ NO ☐ YES *(list name and location of system)*

11. WHO USES COMPLETED REPORT? *(list by command, OP code, etc.)*
USN ACQUISITION PROGRAMS (AIRCRAFT)

12. THIS REPORT IS COMPLETED BY ☒ OPERATING FORCES *(SNDL Part 1)* ☐ SHORE ESTABLISHMENT *(SNDL Part 2)*
IF COMPLETED BY OPERATING FORCES, ARE FLEET CINC COMMENTS ATTACHED? ☐ YES ☒ NO

13. RESPONDENTS

	OPERATING FORCES *(SNDL Part 1)*	SHORE ESTABLISHMENT *(SNDL Part 2)*
A. LIST RESPONDING COMMANDS BY A COLLECTIVE TERM OR BY NAME *(FOR EXAMPLE: FLTCINCS, TYCOMS, NAVAL LABS, ALL LEGSERVOFF, CRUITSTAS, AREA COORDINATORS, ALL OPER AVIATION SQUADRONS, ALL SUBMARINES, ALL SSN, ALL SURFACE SHIPS, MAJOR CLAIMANTS, ALL SHOREACTS W/BEQ/BOQ, ALL COMDS W/DENTISTS, ALL S&S W/MEDPERS, SYSCOMS, COMDS W/GEN MESS, ALL S&S, ALL COMDS W/CIVILIANS, ALL OVS COMDS, ALL ECHELON 2 COMDS)*	(1) ALL OPERATIONAL VAM, VAQ, VF AND VFA SQUADRONS	(2)
B. TOTAL NUMBER OF RESPONDENTS 380	(1)	(2)
C. TOTAL COST TO PREPARE AND SUBMIT THIS REPORT *(from reverse)*	(1) $ 15691.29	(2)

14. ACTION OFFICER

A. NAME, RANK/RATE/GRADE AND TITLE	B. ACTIVITY NAME AND ADDRESS *(include room no.)*
CAIN WILLIAM J LT GRADUATE STUDENT	AIR FORCE INSTITUTE OF TECH WRIGHT PATTERSON AFB OH 45424

C. SIGNATURE	D. DATE	E. PHONE NO.
[signature]	30 APR 93	(513) 236-5012

OPNAV 5214/10 (REV. 9-81) S/N 0107-LF-053-1481

ENCL (1)

Use this worksheet for estimating the total cost to prepare and submit this report. Compute two costs—one for operating forces and one for shore establishments. The hourly rate may be taken from any current pay chart.

OPERATING FORCES COSTS TO PREPARE AND SUBMIT

PAY GRADE	NO. HOURS SPENT	X HOURLY RATE	= PERSONNEL COSTS	+ 25% OVERHEAD	= TOTAL COSTS BY PAY GRADE
0-5	19	$46.37	$881.03	$220.25	$1101.28
0-4	38	$38.77	$1473.26	$368.32	$1841.58
0-3	250	$33.53	$8382.50	$2095.63	$10478.13
≤ 0-2	73	$24.88	$1816.24	$454.06	$2270.30

Total Cost to Prepare and Submit One Report: $______
X ______ Commands Required to Submit = $ ______
X ______ Reports per Year = $ ______

Total Cost to Prepare and Submit * $ 15691.2

*Enter this figure in column 13(c)(1)

SHORE ESTABLISHMENT COSTS TO PREPARE AND SUBMIT

PAY GRADE	NO. HOURS SPENT	X HOURLY RATE	= PERSONNEL COSTS	+ 25% OVERHEAD	= TOTAL COSTS BY PAY GRADE

Total Cost to Prepare and Submit One Report: $ ______
X ______ Commands Required to Submit = $ ______
X ______ Reports per Year = $ ______

Total Cost to Prepare and Submit ** $ ______

**Enter this figure in column 13(c)(2)

SAMPLE COMPUTATION (SALARIES ARE NOT ACCURATE)

PAY GRADE	NO. HOURS SPENT	X HOURLY RATE	= PERSONNEL COSTS	+ 25% OVERHEAD	= TOTAL COSTS BY PAY GRADE
0-2 (Note 1)	.25	7.45	1.86	0.47	2.33
E-8 (Note 2)	3	7.45	22.35	5.59	27.94
GS-4 (Note 3)	1	4.77	4.77	1.19	5.96

Total Cost to Prepare and Submit One Report: $36.23
X 4 Commands Required to Submit = $144.97
X 4 Reports per Year = 579.68

Total Cost to Prepare and Submit $579.68

Note 1: Reviews and signs report.
Note 2: Collects required information; prepares chart; writes report.
Note 3: Types and mails report.

U.S. Government Printing Office: 1982—[illegible] 2-1

ENCL (1)

Aircrew Survey in Appendix B

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FROM: AFIT/LA
2950 P Street
Wright-Patterson AFB OH 45433-7765

SUBJ: Thesis Endorsement

TO: Chief of Naval Personnel (PERS 01JJ)

1. The research effort being conducted by Capt Britt (USAF) and Lt Cain (USN) has the full support of this institution. A justification for having service graduate facilities is the opportunity for students to conduct service-related research beneficial to both the student and the military. AFIT students are encouraged to justify their research and ensure its practicality.

2. In this specific case, the students have chosen a topic in which there is often a lack of data to support decisions. The crew complement issue is one that has often been neglected resulting in work-arounds and less than optimal designs. Technology does provide an opportunity to consider reducing crew size in some mission areas. It is critical that all information that can aid in this assessment be gathered. This effort will tap a valuable, and all too often, neglected source of data. This effort has my strongest support and I highly recommend approval of this request.

Thomas F. Schuppe

THOMAS F. SCHUPPE, Colonel, USAF
Dean
Graduate School of Logistics and
Acquisition Management

From: Lt William J. Cain/Capt Robert E. Britt, Jr. 30 Apr 93
To: Mr. H. Arnoff (Naval Air Systems Command)

Subj: Endorsement of Crew Complement Study

Ref: (a) Phoncon 19 Apr 93, Lt Cain and Mr. Arnoff.

As discussed in ref (a) the enclosed is provided for your review. Please add your endorsement as enclosure 5 to letter and forward the package in the envelope provided to PERS 01JJ. Diane Murphy in that office has indicated that a survey control number can be issued if the package includes your endorsement. We will be in contact with you via phone to ensure receipt and answer any questions you may have. Any amendments you may desire can be incorporated. Thank you in advance for your attention in this matter.

W. J. Cain

WILLIAM J. CAIN, Lieutenant, USN

Robert E Britt Jr.

ROBERT E. BRITT, Jr., Captain, USAF

The Headquarters Naval Air Systems Command letter was included i routing and not made available to the authors.

DEPARTMENT OF THE NAVY
BUREAU OF NAVAL PERSONNEL
WASHINGTON, D.C. 20370-5000

IN REPLY REFER TO
5214
Ser 01J11/3U580634
MAY 24 1993

From: Bureau of Naval Personnel (PERS-01JJ)
To: LT William J. Cain, USN

Subj: NAVY PERSONNEL SURVEY APPROVAL

Ref: (a) Your ltr requesting survey approval of 30 Apr 93
(b) OPNAVINST 5300.8A

1. Your request in reference (a) to survey Navy combat aircrews regarding crew complement issues is approved. Per reference (b) your survey is assigned OPNAV Report Control Symbol: OPNAV 3967-1. This control symbol should be displayed in the Privacy Act Statement of your survey. Your license to administer this survey expires on 30 November, 1993.

2. Upon completion of your survey, please submit the following to: Navy Personnel Survey System, Navy Personnel Research and Development Center, 53335 Ryne Road, San Diego, CA 92152-7250:

a. Variable coding guide, if responses are scored or recoded

b. A file layout guide locating each variable on the file

c. Your final report, thesis, or dissertation

3. The Navy Personnel Research and Development Center (NPRDC) point of contact for surveys is Mr. E. Somer (Code 163), (619) 553-9248.

C W McPeters
C. W. MCPETERS
Special Assistant for
Research Management

Copy to:
AFIT/LA (COL Thomas F. Schuppe, USAF,
Dean, Graduate School of Logistics
and Acquisition Management)
NAVAIR (AIR-531)
NPRDC (NPSS, Code 163)

Appendix B: Combat Crew Requirements Survey

Dear respondent,

Air combat is becoming increasingly technical in nature. Today's aircrews face incredibly complex flying environments. Rising costs have elevated the importance of proper design when procuring combat aircraft. One critical element of aircraft design is crew complement. This survey is designed to measure your (the operator's) input on this important issue. Your participation in this effort may shape future developments. Please take the 40 to 50 minutes required to answer as it will potentially be used to make important design decisions for our next generation aircraft.

The survey is divided into three sections. The first two sections are designed to measure your opinions about six different missions performed by the U.S. Navy. Section I asks questions about your current aircraft and mission. Section II asks questions about your perceptions of the next-generation fighter in a similar format to section I. The third section is designed to gather data on the survey population. What you have to say is important. Please be as accurate and open as possible as you complete this work. Answer by completely darkening appropriate circle next to question on computer scan sheet. It is unnecessary to complete name, date, and identification blocks.

A large part of this survey measures your perceptions of survivability and mission success. When giving responses, use the following definitions to guide your replies:

survivability - The ability to take off from your station, operate in a hostile environment, and return to station successfully.

success - The ability to literally complete your assigned mission. (i.e. for an interdiction mission, the ability to ingress to the target area and accurately deliver fragged ordnance).

If you or your aircraft currently do not perform a listed mission, or you think the question in irrelevant, either leave the question blank or respond with Not Applicable (6).

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

PRIVACY ACT STATEMENT

Authority to request this information is granted by the Chief of Naval Operations under Report Control Symbol: 3700-1 which expires 30/Sep/93.

PURPOSE: The purpose of the questionnaire is to gather data from USN combat aircrews regarding crew complement issues.

ANONYMITY: Information you provide the Navy will be considered only when statistically summarized with responses of others, and will not be attributable to any single individual.

PARTICIPATION: Completion of this questionnaire is entirely voluntary. Refusal to participate in this survey may not result in any adverse action toward members choosing not to respond.

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

Section I. The following questions relate to the capabilities of the aircraft you currently fly. Use the scale below to rate the statements. You will be asked to make judgements regarding mission success and mission survivability across six mission areas based on the capabilities of the aircraft you currently fly. Then you will be asked to postulate how mission success and survivability would be affected by hypothetically varying the crew complement of your aircraft. All questions are asked from both a single-seat and two-seat perspective. You are to assume that capabilities of the single-seat and two-seat versions of your aircraft are identical. If you currently fly a two-seat aircraft, answer the single-seat questions based on a design which enables pilot access to all necessary systems for the mission in question and that the pilot would have been adequately trained in the operation of these systems.

If you currently fly a single-seat aircraft, answer the two-seat questions based on a design which would allow operation of all systems from the front/left seat as they are now, but allow for a second station on the aircraft to optimize use of these systems. Assume also that the NFO would be trained and integrated into the system operation to optimize mission effectiveness. Remember to use the computer scan sheet provided for you.

1	2	3	4	5	6
Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree	Not Applicable

Given the capabilities of my aircraft in the air superiority mission:

1. single-seat missions are likely to be survivable.
2. single-seat missions are likely to be successful.
3. two-seat missions are likely to be survivable.
4. two-seat missions are likely to be successful.

Given the capabilities of my aircraft in the close air support mission:

5. single-seat missions are likely to be survivable.
6. single-seat missions are likely to be successful.
7. two-seat missions are likely to be survivable.
8. two-seat missions are likely to be successful.

1	2	3	4	5	6
Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree	Not Applicable

Given the capabilities of my aircraft in the low/medium threat interdiction mission:

9. single-seat missions are likely to be survivable.

10. single-seat missions are likely to be successful.

11. two-seat missions are likely to be survivable.

12. two-seat missions are likely to be successful.

Given the capabilities of my aircraft in the high threat interdiction mission:

13. single-seat missions are likely to be survivable.

14. single-seat missions are likely to be successful.

15. two-seat missions are likely to be survivable.

16. two-seat missions are likely to be successful.

Given the capabilities of my aircraft in the night/all-weather interdiction mission:

17. single-seat missions are likely to be survivable.

18. single-seat missions are likely to be successful.

19. two-seat missions are likely to be survivable.

20. two-seat missions are likely to be successful.

Given the capabilities of my aircraft in the suppression of enemy air defenses (SEAD) mission:

21. single-seat missions are likely to be survivable.

22. single-seat missions are likely to be successful.

23. two-seat missions are likely to be survivable.

24. two-seat missions are likely to be successful.

Section II. The following questions relate to your perception of the next-generation fighter. Use the scale below to rate the statements. This section deals with the next generation aircraft across the same six mission areas. When responding to these questions, consider both the single-seat and two-seat versions of the next-generation fighter to be optimum designs for their respective configurations and that these aircraft contain your perception of the latest technology for completing the mission in question. Survivability and success definitions remain the same.

1	2	3	4	5	6
Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree	Not Applicable

Given the technology and combat environment of the next generation fighter for the air superiority mission:

25. single-seat missions are likely to be survivable.

26. single-seat missions are likely to be successful.

27. two-seat missions are likely to be survivable.

28. two-seat missions are likely to be successful.

29. Technological improvements in the next generation fighter will decrease overall crew workload on air superiority missions.

Given the technology and combat environment of the next generation fighter for the close air support mission:

30. single-seat missions are likely to be survivable.

31. single-seat missions are likely to be successful.

32. two-seat missions are likely to be survivable.

33. two-seat missions are likely to be successful.

34. Technological improvements in the next generation fighter will decrease overall crew workload on close air support missions.

1	2	3	4	5	6
Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree	Not Applicable

Given the technology and combat environment of the next generation fighter for the low/medium threat interdiction mission:

35. single-seat missions are likely to be survivable.

36. single-seat missions are likely to be successful.

37. two-seat missions are likely to be survivable.

38. two-seat missions are likely to be successful.

39. Technological improvements in the next generation fighter will decrease overall crew workload on low/medium threat interdiction missions.

Given the technology and combat environment of the next generation fighter for the high threat interdiction mission:

40. single-seat missions are likely to be survivable.

41. single-seat missions are likely to be successful.

42. two-seat missions are likely to be survivable.

43. two-seat missions are likely to be successful.

44. Technological improvements in the next generation fighter will decrease overall crew workload on high threat interdiction missions.

Given the technology and combat environment of the next generation fighter for the night/all-weather interdiction mission:

45. single-seat missions are likely to be survivable.

46. single-seat missions are likely to be successful.

47. two-seat missions are likely to be survivable.

48. two-seat missions are likely to be successful.

49. Technological improvements in the next generation fighter will decrease overall crew workload on night/all-weather interdiction missions.

1	2	3	4	5	6
Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree	Not Applicable

Given the technology and combat environment of the next generation fighter for the SEAD mission:

50. single-seat missions are likely to be survivable.

51. single-seat missions are likely to be successful.

52. two-seat missions are likely to be survivable.

53. two-seat missions are likely to be successful.

54. Technological improvements in the next generation fighter will decrease overall crew workload on SEAD missions.

Section III. The following data will be used to categorize the survey results. Please be as accurate as possible.

55. My current rating is:

1. Pilot
2. NFO
3. Pilot with experience as an NFO

56. My current rank is:

1. O-1
2. O-2
3. O-3
4. O-4
5. O-5
6. O-6 or above

57. What aircraft do you currently fly?

1. A-6
2. EA-6
3. F-18
4. F-14

For questions 58 and 59, use the following responses to answer the questions.

1. Under 250
2. 251 - 500
3. 501 - 750
4. 751 - 1,000
5. 1,001 - 1,500
6. 1,501 - 2,000
7. 2,001 - 2500
8. 2,501 - 3000
9. Over 3,000

58. How many flying hours have you accumulated in your current aircraft?

59. How many <u>total</u> military flying hours have you accumulated?

60. Prior to your current aircraft, what other aircraft have you flown?

1. A-6
2. EA-6
3. F-18
4. F-14
5. E-2
6. S-3
7. trainers (as flight instructor)
8. none
9. other

61. ANSWER THIS QUESTION ONLY IF YOU ARE A PILOT <u>AND</u> HAVE ALSO HELD THE RATING OF NFO. What type(s) of aircraft did you fly as an NFO?

1. A-6
2. EA-6
3. F-14
4. E-2
5. S-3
6. Other

For questions 62 - 65, use the scale below to answer.

1. None	5. 301 - 400	9. N/A
2. 1 - 100	6. 401 - 500	
3. 101 - 200	7. 501 - 1000	
4. 201 - 300	8. over 1000	

62. How much combat time do you have in your current aircraft as a <u>pilot</u>?

63. How much combat time do you have in your current aircraft as an <u>NFO</u>?

64. How much <u>total</u> combat time do you have as a <u>pilot</u>?

65. How much <u>total</u> combat time do you have as an <u>NFO</u>?

66. Fill in all of the following blocks which apply to you.

    1. I have been an FRS instructor pilot of an operational aircraft.
    2. I have been an FRS instructor NFO of an operational aircraft.

67. Identify any of the following positions you have held as an operational (not trainer) crew member.

    1. NATOPS instructor/evaluator
    2. Weapons/tactics officer
    3. I have held neither of the above positions.

68. Have you participated in any joint exercises or competitions with members outside your air wing?

    1. Yes
    2. No

69. What do you consider your unit's <u>primary</u> wartime mission? (Identify only one.)

    1. Air Superiority
    2. Close Air Support
    3. Low/medium threat interdiction
    4. High threat interdiction
    5. Night/all-weather interdiction
    6. Suppression of enemy air defenses (SEAD)

70. Identify any of your unit's secondary missions.

1. Air Superiority
2. Close Air Support
3. Low/medium threat interdiction
4. High threat interdiction
5. Night/all-weather interdiction
6. Suppression of enemy air defenses (SEAD)

Feel free to make any written comments about any of the above questions in the booklet itself or a separate sheet of paper. When responding directly to a survey question, list the question number and then your comment. Also feel free to make any general comments. Thank you for your participation. Your responses will be a great help to us. When you finish with the survey, please place the survey, the computer-scored answer sheet, and any additional comments into the envelope provided and drop them into the distribution system. No postage is required if you use government mail. Thanks again.

Appendix C: Raw Data

This appendix contains the raw data used to create the graphs in Chapter 4. This data is the basis for all analyses made in the thesis. There is a difference between the data as presented here and the data as collected by the survey. The survey data ranged from 1 (strongly agree) to 5 (strongly disagree). Because of the mechanization of the optical scanner equipment used to read the data, the inputs to the SAS system (the statistical package used for data analysis) ranged from zero (strongly agree) to four (strongly disagree) or exactly one unit less than recorded. Therefore, as one looks at the data presented in this appendix, a number less than 2 corresponds to a mean response on the agree side of neutral and any number greater than 2 corresponds to a mean response on the disagree side of neutral. The number 2, of course, represents a neutral response. Reducing every response number by one does <u>not</u> affect the analysis in any way. If the number one is added to the mean response data as contained in this appendix, the rating scale from the survey can be used to judge the results.

Also presented in the raw data displays are the number of respondents who answered the question (N) and the standard deviation of those responses (Std Dev). The data is presented according to variable name and not by survey question number. For a detailed explanation of the named variables, reference Tables 3 and 5 from Chapter 4 and accompanying text.

OVERALL MEAN DATA

Variable	Mean	Std Dev	N
CSSURAS	1.7838983	1.5017420	236
CSSUCAS	1.9703390	1.5420246	236
CTSURAS	0.6978723	1.0612622	235
CTSUCAS	0.7659574	1.0980318	235
CSSURCA	1.9341085	1.5047006	258
CSSUCCA	2.1627907	1.5192190	258
CTSURCA	0.7286822	1.0419373	258
CTSUCCA	0.6976744	1.0666844	258
CSSURLT	1.4444444	1.3615357	270
CSSUCLT	1.6925926	1.4651911	270
CTSURLT	0.5000000	0.8760866	272
CTSUCLT	0.4705882	0.8628553	272
CSSURHT	2.5373134	1.4567766	268
CSSUCHT	2.6479401	1.4233635	267
CTSURHT	1.1111111	1.1514766	270
CTSUCHT	1.0371747	1.1870386	269
CSSURNT	2.5461538	1.4604783	260
CSSUCNT	2.8730769	1.3765992	260
CTSURNT	0.8697318	1.1922359	261
CTSUCNT	0.9693487	1.3123010	261
CSSURSD	1.6403162	1.5839833	253
CSSUCSD	1.9565217	1.6360543	253
CTSURSD	0.6482213	1.1712354	253
CTSUCSD	0.6086957	1.1721992	253
FSSURAS	1.3451957	1.3673698	281
FSSUCAS	1.5658363	1.4280757	281
FTSURAS	0.4555160	0.8612573	281
FTSUCAS	0.4285714	0.8562890	280
FSSURCA	1.4607143	1.3300603	280
FSSUCCA	1.7285714	1.3564811	280
FTSURCA	0.5409253	0.8446879	281
FTSUCCA	0.4714286	0.8159947	280
FSSURLT	1.2218310	1.2763473	284
FSSUCLT	1.4805654	1.3948272	283
FTSURLT	0.3957597	0.7618448	283
FTSUCLT	0.3250883	0.7343929	283
FSSURHT	2.0565371	1.4720751	283
FSSUCHT	2.1866197	1.4718911	284
FTSURHT	0.6690141	0.8713892	284
FTSUCHT	0.5669014	0.8273780	284
FSSURNT	2.0319149	1.5052846	282
FSSUCNT	2.3085106	1.4711455	282
FTSURNT	0.5123675	0.8093135	283
FTSUCNT	0.4734982	0.8475062	283
FSSURSD	1.2934783	1.3740825	276
FSSUCSD	1.5090253	1.4386329	277
FTSURSD	0.4528986	0.8232699	276
FTSUCSD	0.3768116	0.7694428	276

OVERALL PILOT DATA

Variable	Mean	Std Dev	N
CSSURAS	1.2720588	1.4425641	136
CSSUCAS	1.4338235	1.5040794	136
CTSURAS	0.7851852	1.1354872	135
CTSUCAS	0.8296296	1.1365091	135
CSSURCA	1.3776224	1.4231694	143
CSSUCCA	1.6083916	1.4488216	143
CTSURCA	0.7112676	1.0076374	142
CTSUCCA	0.6549296	0.9605390	142
CSSURLT	0.9594595	1.1715353	148
CSSUCLT	1.1824324	1.3453733	148
CTSURLT	0.4932432	0.8288720	148
CTSUCLT	0.4729730	0.8366271	148
CSSURHT	2.0945946	1.5401115	148
CSSUCHT	2.1891892	1.4816398	148
CTSURHT	1.1081081	1.1495940	148
CTSUCHT	1.0472973	1.1625357	148
CSSURNT	2.1020408	1.5471348	147
CSSUCNT	2.4693878	1.5138906	147
CTSURNT	0.9178082	1.1832559	146
CTSUCNT	1.0479452	1.2829502	146
CSSURSD	1.1037037	1.4976303	135
CSSUCSD	1.3777778	1.5969498	135
CTSURSD	0.6417910	1.2409249	134
CTSUCSD	0.6119403	1.2009423	134
FSSURAS	0.9731544	1.2941986	149
FSSUCAS	1.1006711	1.2826544	149
FTSURAS	0.5771812	0.9944522	149
FTSUCAS	0.5838926	1.0273337	149
FSSURCA	1.0612245	1.2779719	147
FSSUCCA	1.3333333	1.3155203	147
FTSURCA	0.6258503	0.9305388	147
FTSUCCA	0.5958904	0.9290616	146
FSSURLT	0.8120805	1.1172428	149
FSSUCLT	1.0872483	1.2677544	149
FTSURLT	0.4594595	0.8680134	148
FTSUCLT	0.4324324	0.8663173	148
FSSURHT	1.5704698	1.4807551	149
FSSUCHT	1.7583893	1.4871113	149
FTSURHT	0.7785235	0.9921696	149
FTSUCHT	0.7248322	0.9785473	149
FSSURNT	1.5100671	1.4640625	149
FSSUCNT	1.8187919	1.4706759	149
FTSURNT	0.5771812	0.9092706	149
FTSUCNT	0.5973154	0.9789643	149
FSSURSD	0.8698630	1.1992164	146
FSSUCSD	1.0068493	1.2998492	146
FTSURSD	0.5379310	0.9502974	145
FTSUCSD	0.4827586	0.9287346	145

OVERALL NPO DATA

Variable	Mean	Std Dev	N
CSSURAS	2.4949495	1.2886770	99
CSSUCAS	2.7171717	1.2700667	99
CTSURAS	0.5858586	0.9477158	99
CTSUCAS	0.6868687	1.0463392	99
CSSURCA	2.6403509	1.3043643	114
CSSUCCA	2.8508772	1.3185703	114
CTSURCA	0.7565217	1.0889501	115
CTSUCCA	0.7304348	1.1722054	115
CSSURLT	2.0413223	1.3502882	121
CSSUCLT	2.3223140	1.3675701	121
CTSURLT	0.5040650	0.9354054	123
CTSUCLT	0.4634146	0.8989309	123
CSSURHT	3.0924370	1.1348979	119
CSSUCHT	3.2288136	1.1125624	118
CTSURHT	1.1074380	1.1604715	121
CTSUCHT	1.0166667	1.2229138	120
CSSURNT	3.1238938	1.1030214	113
CSSUCNT	3.3982301	0.9499983	113
CTSURNT	0.8086957	1.2059476	115
CTSUCNT	0.8695652	1.3476538	115
CSSURSD	2.2542373	1.4569987	118
CSSUCSD	2.6186441	1.4197598	118
CTSURSD	0.6554622	1.0926331	119
CTSUCSD	0.6050420	1.1440227	119
FSSURAS	1.7786260	1.3260124	131
FSSUCAS	2.1068702	1.3991861	131
FTSURAS	0.3206107	0.6594540	131
FTSUCAS	0.2538462	0.5611663	130
FSSURCA	1.9090909	1.2506764	132
FSSUCCA	2.1818182	1.2589720	132
FTSURCA	0.4511278	0.7330526	133
FTSUCCA	0.3383459	0.6500259	133
FSSURLT	1.6791045	1.2954562	134
FSSUCLT	1.9323308	1.3991095	133
FTSURLT	0.3283582	0.6225840	134
FTSUCLT	0.2089552	0.5355712	134
FSSURHT	2.6090226	1.2603185	133
FSSUCHT	2.6791045	1.2896391	134
FTSURHT	0.5447761	0.7003294	134
FTSUCHT	0.3955224	0.5754195	134
FSSURNT	2.6165414	1.3298542	133
FSSUCNT	2.8571429	1.2681582	133
FTSURNT	0.4402985	0.6773588	134
FTSUCNT	0.3358209	0.6482368	134
FSSURSD	1.7692308	1.4061794	130
FSSUCSD	2.0687023	1.3822548	131
FTSURSD	0.3587786	0.6453228	131
FTSUCSD	0.2595420	0.5201743	131

A-6 PILOT MEAN INFO

Variable	Mean	Std Dev	N
CSSURAS	2.6785714	1.3892063	28
CSSUCAS	3.1785714	1.0559732	28
CTSURAS	1.3103448	1.6712580	29
CTSUCAS	1.3103448	1.7341826	29
CSSURCA	2.0000000	1.3743685	37
CSSUCCA	2.5135135	1.2387633	37
CTSURCA	0.4473684	0.7240042	38
CTSUCCA	0.0789474	0.2732763	38
CSSURLT	1.5675676	1.2592004	37
CSSUCLT	2.2162162	1.4363367	37
CTSURLT	0.2894737	0.4596059	38
CTSUCLT	0.0263158	0.1622214	38
CSSURHT	3.1081081	1.2198311	37
CSSUCHT	3.4324324	0.7652356	37
CTSURHT	0.9210526	0.9967943	38
CTSUCHT	0.6315789	0.7857189	38
CSSURNT	3.0000000	1.3333333	37
CSSUCNT	3.5945946	1.0397505	37
CTSURNT	0.3421053	0.5824606	38
CTSUCNT	0.1842105	0.3928595	38
CSSURSD	1.2702703	1.0966780	37
CSSUCSD	1.9729730	1.3225919	37
CTSURSD	0.3157895	0.5253191	38
CTSUCSD	0.1315789	0.3425700	38
FSSURAS	1.5263158	1.4470257	38
FSSUCAS	1.9736842	1.1965455	38
FTSURAS	0.2894737	0.5150647	38
FTSUCAS	0.1842105	0.3928595	38
FSSURCA	1.5526316	1.4274788	38
FSSUCCA	2.3684211	1.2610817	38
FTSURCA	0.3421053	0.6688561	38
FTSUCCA	0.1052632	0.3110117	38
FSSURLT	1.1842105	1.2488971	38
FSSUCLT	2.0263158	1.3653401	38
FTSURLT	0.2368421	0.4895784	38
FTSUCLT	0.0526316	0.2262943	38
FSSURHT	2.5263158	1.3097729	38
FSSUCHT	3.1052632	0.9526485	38
FTSURHT	0.5789474	0.6830606	38
FTSUCHT	0.3684211	0.4888515	38
FSSURNT	2.2894737	1.4502170	38
FSSUCNT	3.1315789	1.1191467	38
FTSURNT	0.2894737	0.5150647	38
FTSUCNT	0.2631579	0.7235128	38
FSSURSD	1.0526316	1.1137317	38
FSSUCSD	1.4736842	1.3097729	38
FTSURSD	0.3947368	0.7547856	38
FTSUCSD	0.2105263	0.5769395	38

A6-NFO MEAN INFO

Variable	Mean	Std Dev	N
CSSURAS	2.6363636	1.3988245	22
CSSUCAS	3.3181818	1.0413528	22
CTSURAS	0.6363636	0.9021379	22
CTSUCAS	0.9545455	1.2527027	22
CSSURCA	2.5161290	1.3132902	31
CSSUCCA	3.2580645	0.9989242	31
CTSURCA	0.4193548	0.7199164	31
CTSUCCA	0.1290323	0.3407771	31
CSSURLT	1.8387097	1.2408807	31
CSSUCLT	2.6129032	1.3336021	31
CTSURLT	0.3225806	0.4751910	31
CTSUCLT	0.1290323	0.4275461	31
CSSURHT	3.0645161	1.2092831	31
CSSUCHT	3.6129032	0.7605883	31
CTSURHT	0.9677419	0.8749808	31
CTSUCHT	0.6129032	0.7605883	31
CSSURNT	3.3333333	0.9222661	30
CSSUCNT	3.8333333	0.3790490	30
CTSURNT	0.1935484	0.4774484	31
CTSUCNT	0.0967742	0.3005372	31
CSSURSD	1.8709677	1.4081178	31
CSSUCSD	2.0967742	1.3748900	31
CTSURSD	0.3225806	0.5408078	31
CTSUCSD	0.0967742	0.3005372	31
FSSURAS	1.8000000	1.3995073	30
FSSUCAS	2.4333333	1.4064711	30
FTSURAS	0.3666667	0.5560534	30
FTSUCAS	0.2666667	0.4497764	30
FSSURCA	2.1935484	1.2495160	31
FSSUCCA	2.9354839	1.1235504	31
FTSURCA	0.4516129	0.6752140	31
FTSUCCA	0.2258065	0.5603378	31
FSSURLT	1.8387097	1.3440430	31
FSSUCLT	2.5161290	1.3873468	31
FTSURLT	0.3225806	0.4751910	31
FTSUCLT	0.1290323	0.3407771	31
FSSURHT	2.8064516	1.1081322	31
FSSUCHT	3.3225806	0.9087389	31
FTSURHT	0.5806452	0.6204404	31
FTSUCHT	0.2903226	0.4614144	31
FSSURNT	3.1290323	0.9913605	31
FSSUCNT	3.6129032	0.7605883	31
FTSURNT	0.3548387	0.4863735	31
FTSUCNT	0.1935484	0.4016097	31
FSSURSD	1.6129032	1.4065897	31
FSSUCSD	1.9354839	1.3149267	31
FTSURSD	0.3225806	0.5408078	31
FTSUCSD	0.1935484	0.4774484	31

EA-6 PILOT MEAN INFO

Variable	Mean	Std Dev	N
CSSURAS	1.9166667	1.3113722	12
CSSUCAS	2.1666667	1.2673045	12
CTSURAS	0.9166667	1.1645002	12
CTSUCAS	0.9166667	1.0836247	12
CSSURCA	1.6000000	1.5776213	10
CSSUCCA	1.6000000	1.5055453	10
CTSURCA	0.7000000	1.2516656	10
CTSUCCA	0.9000000	1.2866839	10
CSSURLT	2.0666667	1.4375906	15
CSSUCLT	2.1333333	1.4074631	15
CTSURLT	0.8750000	1.3102163	16
CTSUCLT	0.9375000	1.2893797	16
CSSURHT	2.8000000	1.3732131	15
CSSUCHT	2.7333333	1.4375906	15
CTSURHT	1.1250000	1.3601471	16
CTSUCHT	1.1250000	1.3601471	16
CSSURNT	2.6875000	1.2500000	16
CSSUCNT	2.8125000	1.2230427	16
CTSURNT	0.9375000	1.3400871	16
CTSUCNT	0.9375000	1.3889444	16
CSSURSD	2.6315789	1.4985373	19
CSSUCSD	2.7368421	1.4079972	19
CTSURSD	0.6315789	1.2565617	19
CTSUCSD	0.5789474	1.2612071	19
FSSURAS	1.7333333	1.3870146	15
FSSUCAS	1.7333333	1.3870146	15
FTSURAS	0.6666667	1.1126973	15
FTSUCAS	0.7333333	1.1629192	15
FSSURCA	1.6923077	1.4366985	13
FSSUCCA	1.6923077	1.4366985	13
FTSURCA	0.5384615	0.6602253	13
FTSUCCA	0.5384615	0.7762500	13
FSSURLT	1.6000000	1.5023791	15
FSSUCLT	1.6666667	1.4474937	15
FTSURLT	0.21[illegible]2857	0.4258153	14
FTSUCLT	0.2142857	0.4258153	14
FSSURHT	2.2000000	1.5212777	15
FSSUCHT	2.2000000	1.4242793	15
FTSURHT	0.9333333	1.0997835	15
FTSUCHT	0.9333333	1.0997835	15
FSSURNT	2.4666667	0.9904304	15
FSSUCNT	2.5333333	0.9154754	15
FTSURNT	0.9333333	1.2227993	15
FTSUCNT	0.7333333	1.0997835	15
FSSURSD	2.0555556	1.4337209	18
FSSUCSD	2.1666667	1.3826658	18
FTSURSD	0.5294118	1.0073261	17
FTSUCSD	0.5294118	1.0073261	17

EA-6 NFO MEAN INFO

Variable	Mean	Std Dev	N
CSSURAS	2.6875000	1.2556325	32
CSSUCAS	2.8750000	1.2378441	32
CTSURAS	0.8125000	1.0906494	32
CTSUCAS	0.7187500	1.1425601	32
CSSURCA	2.8157895	1.3122142	38
CSSUCCA	3.0789474	1.4023451	38
CTSURCA	0.8974359	1.2094991	39
CTSUCCA	0.9487179	1.3562471	39
CSSURLT	2.5777778	1.3053890	45
CSSUCLT	2.8000000	1.2172995	45
CTSURLT	0.6595745	1.0483236	47
CTSUCLT	0.5744681	0.9265335	47
CSSURHT	3.3023256	0.9394751	43
CSSUCHT	3.3488372	1.0208242	43
CTSURHT	1.1111111	1.1326201	45
CTSUCHT	0.9111111	1.1245650	45
CSSURNT	3.2558140	0.9021937	43
CSSUCNT	3.4651163	0.8266063	43
CTSURNT	0.8222222	1.0507333	45
CTSUCNT	0.8888889	1.2472191	45
CSSURSD	2.5094340	1.4090728	53
CSSUCSD	3.1320755	1.2715487	53
CTSURSD	0.5454545	0.9587450	55
CTSUCSD	0.4909091	0.9789020	55
FSSURAS	1.9090909	1.2805197	55
FSSUCAS	2.3090909	1.3453999	55
FTSURAS	0.4464286	0.8510879	56
FTSUCAS	0.3272727	0.6953429	55
FSSURCA	2.0545455	1.2082767	55
FSSUCCA	2.2181818	1.1970784	55
FTSURCA	0.5438596	0.8878179	57
FTSUCCA	0.4035088	0.7526062	57
FSSURLT	1.8947368	1.2490598	57
FSSUCLT	2.0701754	1.3739886	57
FTSURLT	0.4310345	0.7748700	58
FTSUCLT	0.2758621	0.6699857	58
FSSURHT	2.6842105	1.2558135	57
FSSUCHT	2.6842105	1.3250053	57
FTSURHT	0.6206897	0.8127835	58
FTSUCHT	0.4137931	0.6498173	58
FSSURNT	2.6842105	1.2558135	57
FSSUCNT	2.9107143	1.1642678	56
FTSURNT	0.5862069	0.8384297	58
FTSUCNT	0.4482759	0.8201928	58
FSSURSD	2.1754386	1.3903084	57
FSSUCSD	2.5614035	1.3095466	57
FTSURSD	0.4655172	0.7994629	58
FTSUCSD	0.3275862	0.6037291	58

F-18 PILOT MEAN INFO

Variable	Mean	Std Dev	N
CSSURAS	0.2075472	0.4539777	53
CSSUCAS	0.1886792	0.4826451	53
CTSURAS	0.7647059	0.9713544	51
CTSUCAS	0.8235294	0.9737737	51
CSSURCA	0.3396226	0.6184160	53
CSSUCCA	0.5094340	0.8906057	53
CTSURCA	0.8823529	1.0516094	51
CTSUCCA	0.8823529	1.0324158	51
CSSURLT	0.1132075	0.3198784	53
CSSUCLT	0.1509434	0.3614196	53
CTSURLT	0.6274510	0.9789951	51
CTSUCLT	0.7058824	0.9652796	51
CSSURHT	0.7169811	0.8632978	53
CSSUCHT	0.7358491	0.8582393	53
CTSURHT	1.1764706	1.1082578	51
CTSUCHT	1.1568627	1.1022259	51
CSSURNT	0.7358491	0.8355317	53
CSSUCNT	1.0943396	1.0609167	53
CTSURNT	0.9019608	1.0247907	51
CTSUCNT	1.0980392	0.9849853	51
CSSURSD	0.0943396	0.2950978	53
CSSUCSD	0.1320755	0.3418128	53
CTSURSD	0.6274510	1.0575592	51
CTSUCSD	0.6862745	0.9271504	51
FSSURAS	0.1509434	0.4555735	53
FSSUCAS	0.1509434	0.4959926	53
FTSURAS	0.8113208	1.2098411	53
FTSUCAS	0.9056604	1.2288855	53
FSSURCA	0.3584906	0.6532269	53
FSSUCCA	0.4339623	0.6936368	53
FTSURCA	0.9245283	1.1240219	53
FTSUCCA	1.0000000	1.0846523	52
FSSURLT	0.1320755	0.3418128	53
FSSUCLT	0.2452830	0.6476484	53
FTSURLT	0.7169811	1.0985543	53
FTSUCLT	0.7735849	1.1031687	53
FSSURHT	0.4339623	0.6936368	53
FSSUCHT	0.4905660	0.6685990	53
FTSURHT	0.9433962	1.1165726	53
FTSUCHT	0.9811321	1.0650129	53
FSSURNT	0.4339623	0.8206338	53
FSSUCNT	0.5849057	0.7704635	53
FTSURNT	0.6792453	0.9358991	53
FTSUCNT	0.7169811	0.9277217	53
FSSURSD	0.1320755	0.3940781	53
FSSUCSD	0.1320755	0.3940781	53
FTSURSD	0.6226415	1.0602325	53
FTSUCSD	0.6603774	1.0731585	53

F-14 PILOT MEAN INFO

Variable	Mean	Std Dev	N
CSSURAS	1.4883721	1.3517553	43
CSSUCAS	1.6279070	1.2914233	43
CTSURAS	0.4186047	0.6630578	43
CTSUCAS	0.4883721	0.6314041	43
CSSURCA	2.0697674	1.4208540	43
CSSUCCA	2.1860465	1.3139510	43
CTSURCA	0.7441860	1.0931175	43
CTSUCCA	0.8372093	0.9983375	43
CSSURLT	1.0930233	0.9713504	43
CSSUCLT	1.2325581	1.0654132	43
CTSURLT	0.3720930	0.5783085	43
CTSUCLT	0.4186047	0.6261203	43
CSSURHT	2.6744186	1.2858373	43
CSSUCHT	2.7209302	1.0762718	43
CTSURHT	1.1860465	1.2584157	43
CTSUCHT	1.2558140	1.3643946	43
CSSURNT	2.8292683	1.3210306	41
CSSUCNT	3.0975610	1.1136624	41
CTSURNT	1.4634146	1.4679503	41
CTSUCNT	1.8292683	1.5953438	41
CSSURSD	1.8076923	2.0003846	26
CSSUCSD	2.0769231	1.9374845	26
CTSURSD	1.1538462	1.9938367	26
CTSUCSD	1.1923077	1.9802875	26
FSSURAS	1.2325581	1.3244443	43
FSSUCAS	1.2790698	1.2597351	43
FTSURAS	0.5116279	0.9353404	43
FTSUCAS	0.4883721	0.9849364	43
FSSURCA	1.3023256	1.3189982	43
FSSUCCA	1.4186047	1.1798418	43
FTSURCA	0.5348837	0.8549251	43
FTSUCCA	0.5581395	0.9335627	43
FSSURLT	1.0465116	1.0680086	43
FSSUCLT	1.0930233	0.9955605	43
FTSURLT	0.4186047	0.8516806	43
FTSUCLT	0.4186047	0.8516806	43
FSSURHT	1.9069767	1.4608209	43
FSSUCHT	1.9767442	1.4055735	43
FTSURHT	0.6976744	1.0126552	43
FTSUCHT	0.6511628	1.0664521	43
FSSURNT	1.8139535	1.4516955	43
FSSUCNT	1.9302326	1.3521649	43
FTSURNT	0.5813953	0.9815575	43
FTSUCNT	0.6976744	1.1450698	43
FSSURSD	1.1621622	1.3019966	37
FSSUCSD	1.2162162	1.3567759	37
FTSURSD	0.5675676	0.9586026	37
FTSUCSD	0.4864865	0.9315943	37

F14 NFO MEAN INFO

Variable	Mean	Std Dev	N
CSSURAS	2.3023256	1.2636848	43
CSSUCAS	2.3023256	1.2636848	43
CTSURAS	0.4186047	0.8516806	43
CTSUCAS	0.5348837	0.8549251	43
CSSURCA	2.6511628	1.2888482	43
CSSUCCA	2.4418605	1.3147936	43
CTSURCA	0.9069767	1.1713637	43
CTSUCCA	1.0000000	1.2535663	43
CSSURLT	1.6744186	1.3402368	43
CSSUCLT	1.6511628	1.3071911	43
CTSURLT	0.4883721	1.0549677	43
CTSUCLT	0.5813953	1.0742120	43
CSSURHT	2.9069767	1.2689319	43
CSSUCHT	2.8095238	1.3110803	42
CTSURHT	1.2325581	1.3773198	43
CTSUCHT	1.4523810	1.4849223	42
CSSURNT	2.7631579	1.3642979	38
CSSUCNT	2.9473684	1.2069029	38
CTSURNT	1.3243243	1.5644320	37
CTSUCNT	1.5405405	1.6598962	37
CSSURSD	2.2500000	1.5240015	32
CSSUCSD	2.3125000	1.4013243	32
CTSURSD	1.1935484	1.5148015	31
CTSUCSD	1.3548387	1.5609482	31
FSSURAS	1.5909091	1.3523138	44
FSSUCAS	1.6363636	1.3824634	44
FTSURAS	0.1162791	0.3243530	43
FTSUCAS	0.1395349	0.4129681	43
FSSURCA	1.5681818	1.2648693	44
FSSUCCA	1.6136364	1.1657099	44
FTSURCA	0.3255814	0.5219437	43
FTSUCCA	0.3488372	0.5725349	43
FSSURLT	1.3181818	1.2899022	44
FSSUCLT	1.3720930	1.2728531	43
FTSURLT	0.2093023	0.4658908	43
FTSUCLT	0.1860465	0.4501753	43
FSSURHT	2.3488372	1.3781237	43
FSSUCHT	2.1818182	1.2988855	44
FTSURHT	0.4186047	0.5868624	43
FTSUCHT	0.4418605	0.5478236	43
FSSURNT	2.1162791	1.4993539	43
FSSUCNT	2.2045455	1.3738343	44
FTSURNT	0.3023256	0.5133867	43
FTSUCNT	0.2790698	0.5035863	43
FSSURSD	1.3250000	1.2887581	40
FSSUCSD	1.4878049	1.2673190	41
FTSURSD	0.2250000	0.4229021	40
FTSUCSD	0.2250000	0.4229021	40

COMBINED DATA FOR TECHNOLOGY

VARIABLE	N	MEAN	STD DEV
TAS	287	1.7700348	1.4827944
TCA	289	1.7370242	1.4860624
TLT	289	1.4982699	1.4580347
THT	289	1.7785467	1.5341336
TNT	287	1.6620209	1.4867904
TSD	287	1.4843206	1.4767184

PILOT DATA

VARIABLE	N	MEAN	STD DEV
TAS	150	1.4066	1.4099
TCA	148	1.3919	1.4411
TLT	149	1.1409	1.3152
THT	149	1.4362	1.4444
TNT	148	1.3446	1.3488
TSD	147	1.0544	1.2263

NFO DATA

VARIABLE	N	MEAN	STD DEV
TAS	131	2.0763	1.3735
TCA	134	1.9851	1.3376
TLT	134	1.7761	1.4069
THT	134	2.0522	1.4680
TNT	134	1.8881	1.4698
TSD	131	1.7252	1.4091

A-6 PILOT DATA

VARIABLE	N	MEAN	STD DEV
TAS	38	1.7894	1.3980
TCA	38	1.8947	1.5208
TLT	38	1.3684	1.3441
THT	38	1.8684	1.5452
TNT	38	1.6579	1.4755
TSD	38	1.4211	1.4072

A-6 NFO DATA

VARIABLE	N	MEAN	STD DEV
TAS	30	2.0666	1.2299
TCA	31	2.1290	1.3100
TLT	31	1.7097	1.3215
THT	31	2.0322	1.4940
TNT	31	2.0000	1.4142
TSD	31	1.7419	1.4134

EA-6 PILOT DATA

VARIABLE	N	MEAN	STD DEV
TAS	16	1.8152	1.5152
TCA	14	1.6428	1.4991
TLT	15	1.5333	1.5522
THT	15	1.8000	1.5675
TNT	15	1.5714	1.4525
TSD	17	1.5882	1.3719

EA-6 NFO DATA

VARIABLE	N	MEAN	STD DEV
TAS	56	1.9643	1.4008
TCA	58	1.7586	1.3417
TLT	58	1.7241	1.4116
THT	58	1.8621	1.4802
TNT	58	1.7241	1.4240
TSD	58	1.7586	1.5138

F-18 PILOT DATA

VARIABLE	N	MEAN	STD DEV
TAS	53	0.9434	1.1996
TCA	53	1.0377	1.3150
TLT	53	0.7924	1.1327
THT	53	0.9622	1.2083
TNT	53	1.0000	1.1266
TSD	53	0.5849	0.8420

F-14 PILOT DATA

VARIABLE	N	MEAN	STD DEV
TAS	43	1.4884	1.5019
TCA	43	1.3023	1.4063
TLT	43	1.2325	1.3599
THT	43	1.5116	1.4536
TNT	43	1.4186	1.4012
TSD	39	1.1026	1.2311

F-14 NFO DATA

VARIABLE	N	MEAN	STD DEV
TAS	43	2.1628	1.4463
TCA	43	2.1628	1.3615
TLT	43	1.8372	1.4949
THT	43	2.2325	1.4114
TNT	43	1.9302	1.5491
TSD	40	1.6000	1.2567

Appendix D: Survey Comments

Introduction

This appendix contains comments from those crewmembers who took the time to verbally state their opinions in writing. Some comments may help to explain certain results found in the data. The comments range from question elaboration to suggestions for future acquisition strategies. These comments were used extensively in the writing of Chapter 5 and in many cases support given explanations in that chapter. Though not as numerous as the surveys themselves, the comments serve to uncover possible mind-sets unique to an aircraft community or subcommunity. Of particular importance are those comments from pilots who flew both one-seat and two-seat aircraft in a tactical environment.

1. O-3, A-6 pilot.
Operation Southern Watch has demonstrated again that defensive action in the cockpit takes precedence over offensive action. In a two-place aircraft, one person can maintain an uninterrupted look-out (and monitor ECM, HARM, ALR-67) while the other works the navigation and, most importantly, finds the target and optimizes weapons delivery.

2. O-3, A-6 pilot.
In the debate of dual-seat vs. single-seat designs, the easiest way to predict mission effectiveness and survivability is to break down the tasks that must be performed. Consider an air-to-ground interdiction mission against a point target. Assume the aircraft is a wingman on a high altitude mission delivering an LGB:

Tasks	Inside or outside
1. maintain tactical formation	outside
2. navigate/maintain timing	inside
3. identify target on radar	inside
4. transition/handoff to FLIR	inside
5. fly to weapons release point	inside
6. employ weapon	inside/outside
7. track target post release	inside
8. perform off target maneuvers	inside/outside
9. rejoin lead	outside
10. continuously scan RHAW gear	inside

11. continuously scan outside — outside
12. continuously preemptively maneuver — inside/outside

Especially during weapons release one man is so task saturated that he would be unable to prosecute the threat effectively without sacrificing an outside scan for enemy anti-air threats. Keep in mind this is a simple mission. It does not include air superiority factors.
Bottom line: Technology advances will allow reduction in types and numbers of aircraft on strikes but will not reduce requirements for one man focused outside and one targeting inside.

3. O-3, A-6 pilot.
I feel the aircrew workload will increase due to more restrictions on airspace/ROE/additional long range weapons/future ballistic missile/cruise missile threat; and technology always seems to be trailing the real world scenario.

4. O-3, A-6 pilot.
Two seats are better than one. Anything that reduces pilot workload, in my opinion, will help to develop situational awareness. I feel S.A. is a critical component of combat survivability and mission completion.

5. O-5, A-6 pilot.
Unless technology greatly eases crew loading in a high-tempo/high-threat scenario, dual-seat will always be more successful in mission completion. Survivability is not as seriously affected by dual-seat as is mission completion. Thanks for your time.

6. O-3, A-6 pilot and previous NFO.
After flying both single and two-seat aircraft, and a two-seat aircraft in a med. threat environment, I feel that it is a waste of time thinking about single-seat aircraft for the attack role. Simply look at the bombing results for those aircraft in a combat environment. New technology will only make the NFO's job more important.

7. O-4, A-6 pilot.
Coming from a two-crew aircraft I strongly endorse the use of an NFO in future aircraft procurement plans. The technology will certainly ease the workload, but the extra set of eyes and another brain will directly equate to a lower mishap rate and a more survivable and successful platform.

8. O-3, A-6 NFO.
An NFO means increased S.A. in a fighter/SAM/ECM threat and always multiplies aircraft capability regardless of the technology present by allowing the dividing/sharing of tasks in the cockpit.

9. O-3, A-6 pilot and previous NFO.
In general I feel a two-seat aircraft is much more successful and has a higher survivability than any single-seat aircraft. It is getting easier with new generation aircraft to overload a single person. The

more info he is faced with, the more "spills out the bucket". Survivability then becomes more important than success. Then if they aren't successful why send them in. With two crewmembers, each can process info important to their own task and not become overwhelmed.

10. O-3, A-6 NFO.
Advanced tech. will help in all aspects of war. However, history both recent and not so recent (Vietnam) will speak for the comparison between single-seat and dual-seat. There is no way a single-seat aircraft can navigate to the target, react to the threat (i.e. maneuver, expendables, fly the aircraft, find and hit the target) in a med to high threat environment with any positive degree of success as compared to the dollars the tax payer has put into that single-seat aircraft.

11. O-5, A-6 NFO.
Technology will allow systems to be more user-friendly and time-consuming but it will also add complexity and the ability to add more systems. The addition of a second crewmember will always give you a more capable aircraft and the ability to add systems to enhance the aircraft which will overtax the pilot which the systems were initially designed to operate. The money you save by going single-seat is a false savings offset by the $ spent for increased aircraft loss due to overtasking and the operational loss of flexibility and inability to add new subsystems due to overtasking the pilot.

12. O-2, A-6 NFO.
Questions 17, 18, 45, 46: I honestly feel that the mission of night/all-weather interdiction cannot be successful in a single-seat aircraft.
Questions 29, 34, 39, 44, 49, 54: The technological improvements in the next generation fighter will give the aircrew more data than they currently have. Currently faced problems may become easier, but with more data presented, more decisions will have to be made. That is why I strongly disagree with these questions.

13. O-3, A-6 pilot.
The questions in the survey are extremely vague. Asking about success and survivability without mentioning specific threats, ordnance and target specs is impossible to answer. Also, two-seat aircraft are set up for two people and pretending that all systems can be run from one side just to answer a question will get totally ambiguous answers. On the other hand, its great to see that they are questioning the aircrew about new aircraft.

14. O-4, A-6 pilot.
This survey is very general in nature. As the Navy moves toward greater multi-role aircraft the workload for pilots, pilots/BNs will never decrease as technology advances. Advances in technology seem only to increase the overall workload that is expected of aircrew. New missions, more options, increased weapons complexity, increased

capability of IADS, increased airwing integration and additional joint operations require that today's or tomorrow's aviator use technology to decrease specific task workloads and effectively utilize task management in our favor to prevent aircrew overload.

In my opinion, it is ludicrous that any service would contemplate sending a single pilot only over enemy territory in a task load saturated environment such as night/all-weather interdiction, self-escort SEAD, or night air-superiority missions. It would seem intuitively obvious to me that two persons sharing a heavy task load would be able to effectively complete a mission with less fatigue and greater confidence than an overloaded single-seat aviator.

It is still the threat that you don't see that will kill you the most effectively. If your mission carries you near enemy territory in a high threat environment day or night, two sets of eyeballs in each cockpit would be my recommendation for our future strike/fighter aircraft.

15. O-3, EA-6B NFO.
Single-seat in today's high technology environment has a place, but only as a bit player, not the cornerstone of our attack. There is just too much happening for any mission more complex than just firing HARM or a Sparrow and landing for a single pilot (or NFO for that matter) to handle. No matter how much help the pilot receives from technology, he still has to monitor the flying, track his wingman, follow the mission plan, maintain timing, and keep S.A. In addition, multi-seat aircraft offer more flexibility to handle an uncertain future. More critical than multi-seat/single-seat operations is fuel. Don't saddle us with another F-18-type tanking nightmare. In a high-threat environment we would be in a hurt locker.

16. O-2, EA-6B NFO.
This questionnaire is not designed for a four-place aircraft like the EA-6B. If we functioned as a one- or two-seater, then we would not be able to fulfill our mission.

17. O-3, EA-6B NFO.
Aircraft-to-aircraft data links and aircraft-to-surface data links should be a primary concern for all future aircraft to increase connectivity, cooperation, situational awareness and combined operations. (Force multiplication by letting the specialists- EW, air-to-air, air-to-ground, control and see all players via data links and new displays/GPS information.)

18. O-3, EA-6 NFO.
As an NFO my opinion may be biased, but I feel that single-seat fighters and attack aircraft are obsolete. As technology improves, the threats that we must be concerned with in the aviation community will increase in number and improve in capability. During the air strikes against Iraq on 13 and 16 Jan 93, a significant number of mu fellow aviators in the F/A-18 community complained about being overtasked. This was very

evident in the number of targets missed by the F-18s on the 13 Jan 93 strike, compared to the success of the A-6s that same night. Two well-trained heads in a cockpit will always be better than one, whether it is in the attack role or the fighter role.

Another distressing trend that we face is the decline of the Navy's ability to conduct medium range strikes. As the Navy moves towards replacing older aircraft with the F-18, our capabilities are greatly reduced. It was proved time and again while we were in the Persian Gulf that the F-18 could not adequately fill the shoes of the A-6 in the attack role, or the F-14 in the fighter role. The F-18 is a capable aircraft and complements the airwing, but it will never have what it takes to do all that is asked of it.

19. O-3, EA-6B NFO.
This survey does not really apply to my aircraft, the EA-6B. For some missions, an NFO would not be required in the front seat. However, in a real combat environment the NFO is indispensable. The bottom line as I see it in regard to two-seat vs one-seat for attack aircraft is that the A-6 can hit its target at night and the F-18 can't and has a difficult time acquiring the target as illustrated on the 13 Jan 93 strike on Iraq of which I took part. In my opinion, two heads in the cockpit are better than one in a high threat arena and workload is reduced significantly. Also of concern is a fighter that has the ability to stay on station an ample amount of time. Any version of the F-18 does not fit this description and the Navy has given away its ability to conduct a medium range strike. All of these points were painfully apparent during my time in the gulf.

20. O-3, EA-6B NFO.
General input: Technology (read: computers) is great for presenting information. It is suspect with regard to interpreting information and miserable for decision-making . A man is needed for the latter two tasks, and as information volume, need for interpretation and requirement for decision-making increase with the threat, it will become impossible for one man to do it all and fly the plane too. No matter how many CRTs you put in front of him, he has only one mind.

21. O-4, EA-6B NFO.
EW aircraft need:

- to be fast,
- hard kill weapons (HARM),
- tactical data link connectivity,
- long loiter time,
- a min of two aircrew, three would be better, four is great,
- long-range/escort capability,
- many radios with secure capability.

22. O-3, EA-6B pilot.
The Strike Eagle (F-15E) seems to be the way to go! The USN needs a similar aircraft. The F-18D is good, but seems to have short legs and a

smaller payload than the Strike Eagle. The USN needs a supersonic jammer! The closer we get, the better we do. Faster is better.

23. O-3, EA-6B pilot.
This survey is geared towards multi-role fighters. VAQ guys jam and shoot HARM. Our new aircraft is ADVCAP. It will jam and shoot HARM more accurately. (By the way we are a four seat aircraft and this single-seat/two-seat discussion is a waste of time.)

24. O-5, F/A-18 pilot.
Technology should make combat easier! But you must train the operator, and he should be maintained at a high state of readiness. Technology in itself doesn't make us ready to survive and win--training does. Single vs two is not as much an issue. Training vs not training is! Your questions sample only half the issue. The other half is that training is required.

25. O-3, F/A-18 pilot.
My response to questions 1, 3, 13, and 15 were not a reflection on the single-seat/multi-seat argument but on the current state of Navy EW systems which are substandard. I believe this will improve in the next generation of aircraft and my answers to subsequent questions reflect this.

In the air superiority area I expect single-seat and multi-seat platforms to come out even. There are advantages and disadvantages to both. I do think crew coordination in this area is critical to multi-seat operations and I believe this is a perishable skill. Poor crew coordination/training will leave a multi-seat aircraft at a disadvantage against a single-seater. The opposite is true if there is good crew coordination. In section and division work I think the coordination of four or eight people is much more difficult and is handled more effectively in the single-seat community. I believe multi-seaters will be too busy trying to sort out who is who. Single-seaters tend to prioritize, concentrating on mission success, possibly to the detriment of survivability.

I believe a single-seat aircraft with an accurate day visual bombing system is the best platform for close air support. The Hornet is such a platform. Multi-seat strike aircraft tend to focus on the all-weather radar mission and their day visual systems are not as accurate. Accuracy is the most important quality in this arena.

Single-seat aircraft, especially with NVGs, can operate effectively at night in the air-to-ground role. They have some effectiveness in all-weather operations. This is where the multi-seat aircraft really shines and the Navy needs to keep a multi-seat aircraft in this role.

Obviously it costs less to operate and replace single-seat aircraft and you only have to pay half the officers. They also take up less room on a ship. Technology is beginning to allow us to close the gap in the areas that multi-seat aircraft have an advantage without the associated disadvantages. I do believe we need to split Navy airwings

between single-seat and multi-seat. I believe the breakdown occurs as follows:

Single-seat	Multi-seat
primary fighter	primary fighter
primary CAS	secondary CAS
primary interdiction	primary interdiction
primary SEAD	primary SEAD
secondary night/all wx	primary night/all wx

We can do this with two aircraft, one single-seat and one multi-seat. This would provide us all the flexibility we need.

26. O-4, F/A-18 pilot.
Technological improvements don't always lessen the workload.

27. O-4, F/A-18 pilot.
Any strike mission's probability of success will be reduced by an extra person in the chain of events to put armed ordnance on target. Training will still be the single most important factor in both success and survivability in any aircraft (single- or dual-seat). Technological advances must be focused on a particular area. It should be a combination of ergonomic advances and warfare capability upgrades. Some upgrades over existing equipment will automatically accomplish ergonometric advance (RWR gear in particular). My unit trains nearly equally in air superiority, strike (low/med/high threat), and SEAD. Close behind is CAS and night/all-weather strike.

28. O-3, F/A-18 pilot.
Its hard for me to choose only one answer for question #70. The Hornet does many missions well and is a definite threat in the air superiority, SEAD, and night/all-weather interdiction as well. However, my answers are based on my recent experience as part of a Navy airwing with operations in Somalia and Iraq.

29. O-3, F/A-18 pilot.
With the current technology in the F/A-18 and its user-friendly weapons systems, all the above missions (#69, 70) can be accomplished successfully with a single seat. Simply change the loadouts and streamline a training program to keep pilots current.

30. O-3, F/A-18 pilot.
The basic question of this survey asks: Is one seat better than two seats or vice versa? With modern and future aircraft, because of technological improvements, the ability of a single-seat aircraft (although possibly approaching task saturation) will outperform a two-seat aircraft where crew coordination and two men in the loop relying on communication will suffer time delays and a longer decision process matrix.

31. O-3, F/A-18 pilot and former NFO.
Some tough questions as generally two people are always better than one if you're talking about same aircraft (i.e. F/A-18C and F/A-18D). I think air to air is better-suited for one person while night attack is two. Also hard to quantify next generation fighter and what types of updates will be present. Most of us compare A-6 to F-18 and we all know the A-6 is dead. If the next generation fighter is as far ahead as the F-18 is compared to the A-6, then two people might not be necessary at all.

I think you need to consider on station time with two-seat vs single-seat/tanker availability etc. Although flying lot XIII Hornets (night attack) is a blast, we all realize two people would be great. If you are gonna go strictly single-seat, training hours need a huge boost. It is very difficult for a single-seat pilot to master A/A, SEAD, CAS, A/G, and night strike. With two people, weapons systems knowledge is easier to manage, not just flying skills and task saturation. Training is the key. Great job on the survey! I would like to see the final report.

32. O-4, F-14 NFO.
I recognize the difficulty in quantifying this type of survey, but if I may expand on my answers to emphasize my feelings:

a. improved technology/systems will ease the pilot or aircrew workload, but increasing mission complexity will not enable a single pilot to maximize his aircraft's mission performance as well as two aircrew splitting the workload.

b. at some point during any mission (SEAD, CAS, A/A) the pilot must intentionally focus his attention in order to deliver ordnance. This will always detract from single-seat survivability when compared to multi-seat aircraft.

c. Air superiority is generally a more controlled situation, which can use pre-briefed roles and tactics in comparison to interdiction/CAS. I believe a strictly air superiority aircraft could function as a single-seat version, but it would not be as survivable in the end game.

33. O-3, F-14 NFO.
Comparisons between the F-15, F-16, and F-14 show that technology is required for the air superiority mission and can be managed adequately by a single aircrew. A RIO is often there to supplement the deficiencies in technology in this regard. Night/all-weather attack missions can easily overload a single aircrew. With multi-mission aircraft being the platform du jour, it makes sense to have two aircrew in these aircraft.

34. O-3, F-14 NFO.
In combat, there is no substitute for a second pair of eyes to see the otherwise unseen missile launch. This directly affects survivability.

35. O-3, F-4 pilot.
I believe the air superiority role can be handled by a single crewmember only. I think to do the strike job, even with technology improvements, having two people in the cockpit increases mission success and safety.

36. O-4, F-14 pilot.
Complex crew coordination issues (i.e. timely communications, distracting inputs from "different-minded" crewmembers), detracts from overall mission survivability/probabilities of mission success. Single-seat is best.

37. O-2, F-14 NFO.
Survey is a great idea but I think a verbal forum should also be included as a supplement. Tempering this feedback is also a good idea as I am a LTJG that has only been in a fleet squadron for eight months.

38. O-3, F-14 pilot.
The next tactical fighter should combine the following:

- -the range and radar ranges of the F-14
- -the ordnance versatility of the F-18
- -the top speed of the F-14
- -the acceleration of the F-16
- -the weapons systems ease of use of the F-18
- -the load factor of the F-16
- -and a refreshment system (Coke or Pepsi will do).

Your questionnaire is a little too redundant. If a single-seat mission is survivable/successful, a two-seat would certainly be so.

39. O-4, F-14 pilot with single-seat experience.
As you can see by my responses, I am not a fan of two-seat aircraft. I believe more harm has been done to the F-14 community because there are two seats than if it were a single-seat aircraft. The evidence for this is simple. Look to any single-seat aircraft (F-18, F-15, and F-16) and you will see that the capabilities are far above those of an F-14. The reason these aircraft are so good is because they must work for one man and by one man to operate properly and efficiently. Fixes to the Tomcat have been hap-hazard and ill-conceived because there are two men. Operations are doled out in piecemeal to make each feel he contributes when in actuality, he detracts.

I have over 300 hours in an F-16 operating a radar, launching expendables, and managing RHAW information while I functioned as an aggressor pilot. I have seen both worlds and know what works. I have had the opportunity to critique the performance of Navy F-14 and F-1S crews in addition to Air Force F-15 and F-16 crews. The single-seat aircraft outperformed the dual-seat aircraft because of one reason. The single-seat pilot is involved in every decision. From moving the radar cursors, evaluating locks and RHAW information and maintaining a lookout. While the proponents of two seats see this as a detractor, I do not. These proponents fail to grasp what a fighter/strike pilot must do. He must weight all the information available to him and make his

best decision. When only half of the variables are known, a poor decision is made. People must remember that flying while a visual art, is complemented by tactile stimulation. "Seat of the pants", whether it comes from the pants or the fingers (i.e. manipulating a radar display etc.) helps the pilot decide the best course. I implore you, never make another two-man fighter again. It does not work!

40. O-3, F-14 NFO.
The F-14A would greatly benefit from improved RWR gear in combat. Two pairs of eyes are twice as good as one for picking up SAMs and bogeys.

41. O-4, F-14 NFO with single-seat experience.
I have flown all types of F-14s (A, B, D) and the F-18 while assigned to the Navy Operational Test Squadron. I feel that a tactical aircraft with a fully integrated cockpit such as the F/A-18 has advantages over two-seat in a strictly A/A mission, when compared to a relatively poorly integrated F-14. However, when tasked to perform multi-mission (air-to-surface with an A/A threat and S/A threat) multi-threat, the F-14 would have an advantage if equipped with equal DECM equipment--F-15E being the ideal. Generally if one crewmember will have to concentrate his scan on one thing (targeting) for more than 5 - 10 seconds, he needs a second crewmember. If everything is automatic and integrated, one pilot is better. Multi-crewed F-14s have saved themselves many times around the aircraft carrier at night where F-18s have been lost due to S.A. loss.

42. O-3, F-14 NFO.
I had the good fortune to work on the AX/AFX program while an instructor at the Navy Fighter Weapons School (Topgun). This experience coupled with 300 hours in the back seat of a TF-16N and 1200 hours in the F-14A and real world missions, performing demanding simulations has given me some insight into this subject.

First: Most air superiority missions in a 2 vs UNK environment can be performed very effectively in a single-seat aircraft. In fact, in some cases single-seat aircraft are more desirable. However, as the missions become more complex, task loading; even in the most advanced cockpits, becomes overwhelming and important information starts dropping out of even the most experienced pilots scan. (4 vs UNK scenarios)

Second: In a high threat/high mission tasking environment (self-escort, interdiction, etc..) no technology that will be available in the next fifteen years will make up for a second crewmember. I gleaned this information from extensive contractor briefs for the AX/AFX project.

Third: While the Navy's F/A-18 is an outstanding aircraft with one of the most user-friendly cockpits in the world, operational experience (most recently Operation Southern Watch/strikes in Iraq) has shown that the average fleet F-18 pilot is overwhelmed with night, high task loaded hostile environment and simple air to ground delivery suffers (F/A-18 one for eight on targets hit).

With the declining defense dollar and the Navy's demand for no single-mission aircraft, two-seat aircraft, when properly integrated (i.e. F-15E/F-18D) are the only way to go!

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Vita

Captain Robert E. Britt, Jr. was born on 7 June 1959 in St. Louis, Missouri. He graduated from Riverview Gardens Senior High School in 1977. Following high school, he attended the United States Air Force Academy. He graduated in May of 1981 with a Bachelor of Science in Aeronautics. In June of 1982, he received his pilot wings after completing Undergraduate Pilot Training at Vance Air Force Base, Oklahoma. Following A-10 upgrade training, he was sent to RAF Bentwaters in the United Kingdom where he accumulated more than 1000 A-10 hours in three years. From Bentwaters, he went to SOS in residence enroute to Columbus Air Force Base in Mississippi where he became an instructor pilot in the T-38. In the spring of 1989, he completed his UPT instructor pilot tour and attended F-16 upgrade training at MacDill Air Force Base in Florida. He was assigned to Shaw Air Force Base in South Carolina. In August of 1990, He was sent to the United Arab Emirates as part of a coalition force to support Operations Desert Shield and Desert Storm. After Desert Storm and another year at Shaw, he was chosen to attend the Air Force Institute of Technology to study Systems Management. Captain Britt is a senior pilot with more than 2500 total flying hours in the F-16, A-10, and T-38. He is a combat veteran with 30 combat missions totalling more than 100 combat hours. Captain Britt is married to the former Alice Coakley from Colorado Springs, Colorado. They have three children, Emily, Laura, and Andrew.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1993	Master's Thesis

4. TITLE AND SUBTITLE
A STUDY OF USN AIRCREW ATTITUDES REGARDING TECHNOLOGY'S ABILITY TO REPLACE THE NAVAL FLIGHT OFFICER ON TYPICAL COMBAT MISSIONS CARRIER BASED AIRCRAFT ARE TASKED TO PERFORM

5. FUNDING NUMBERS

6. AUTHOR(S)
Robert E. Britt, Captain USAF and
William J. Cain, Lieutenant, USN

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology, WPAFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GSM/LAR/93S-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Headquarters Naval Air Systems Command
Air 531-C
1421 Jefferson Davis Highway
Arlington VA 22243

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This study analyzed survey responses of 290 Navy pilots and Naval flight officers (NFOs) regarding their perceptions of technology's ability to replace the NFO in typical combat missions carrier-based aircraft are tasked to perform. The study is a follow-on to a similar USAF effort conducted with pilots. The objective of this study is to provide operator input to the critical crew complement issue. These missions vary significantly in complexity and in demands placed on the aircrew. The survey instrument and anlysis methods were designed to detect and evaluate these differences. The USAF study concluded that the perception of a requirement for additional crewmember(s) varied with mission and type aircraft flown. The USN aircrew analysis indicates perceptions also vary in both of these categories. There is evidence to suggest that technology is making gains with regard to aircrew workload in certain mission areas. On the other hand, there are also areas where an additional crewmember is considered a requirement. This study will examine each of these mission areas in both a current and future technology context. From this examination a relative ranking of NFO contribution in all of the mission areas analyzed is provided.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Aircrew, Naval Flight Officer, Pilots, Technology	206
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

AFIT Control Number AFIT/GSM/LAR/93S-1

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